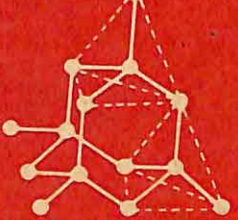
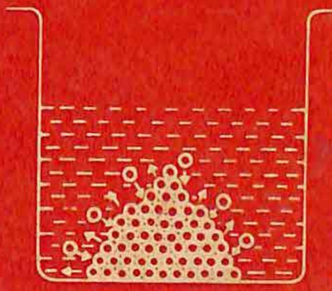
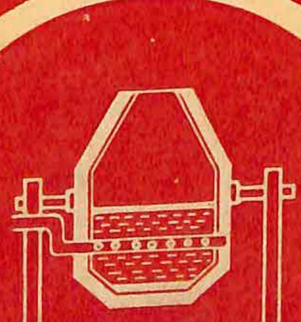
Revision in CHEMISTRY 2

D P GOEL
S P MITTAL







ORIENT LONGMAN

REVISION IN CHEMISTRY

Revision in CHEMISTRY

Volume 2

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Preface

This book is aimed primarily at the students of classes 9 and 10 offering the Science Course A of the All India and the Delhi Secondary School Examination. It has been written with the dual purpose of providing the subject matter to the students in a crisp form, as well as aiding them in preparing for the examinations.

The subject matter is presented in a question-answer format in clear and simple language. In each chapter important definitions and laws have been given at the beginning, and the physical and chemical properties of elements provided in a tabular format, to serve as a ready reckoner. As a further aid to preparation for the examination, exercises have been provided at the end of each chapter. SI units have been used throughout.

This is the second of the two volumes, covering the Class 10 syllabus.

The authors would welcome comments and suggestions from students and teachers who use the book.

D.P. Goel
S.P. Mittal

May 1983

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Syllabus for Classes IX and X

(All India and Delhi Secondary School Examination, Chemistry, Course A)

1. Importance of Chemistry in Everyday Life (non-evaluative).

2. Elements, Compounds and Mixtures

Elements, compounds and mixtures, types of mixtures and their separation.

3. Chemical Communication

Symbols of elements, chemical equations and simple calculations based on chemical equations.

4. Behaviour of Gases

Introduction, volume-pressure, volume-temperature and pressure-volume-temperature relationships for a gas (combined gas law), Kelvin temperature scale, Gay-Lussac's law, Avogadro's law, mole concept, gram molecular volume of a gas at standard temperature and pressure. Simple calculations based on applications of gas laws and the mole concept.

5. Structure of the Atom

Electrical nature of matter, electric discharge through gases under reduced pressure, cathode rays and positive rays, evidence for the existence of nucleus; protons, neutrons and atomic number, nuclear model of an atom, distribution of electrons in shells (K, L, M, N), electronic configurations of first 20 chemical elements, isotopes, valence electrons.

6. Chemical Bonding

Inertness of noble gases, electrovalent and covalent bonds, properties of electrovalent and covalent compounds, formation of some elementary molecules, e.g. H_2, O_2, N_2, CH_4, CCl_4, and C_2H_2 with special reference to single, double and triple bonds, polarity in HCl molecule.

7. Periodic Classification of Elements

Periodic classification (mention of Mendeleev's work), modern basis of periodic classification (periodic law), long form of periodic table, idea of groups and periods and their general characteristics.

8. The Halogens

Occurrence in nature, general methods for the preparation of halogens, laboratory preparation and properties of chlorine, relative reactivity of halogens (displacement reactions), detection of halogens (except fluorine), uses of halogens. Hydrogen chloride and hydrochloric acid, preparation in laboratory, properties and uses. Preparation and uses of bleaching powder.

9. Oxygen and Sulphur

Occurrence of oxygen and sulphur, atmospheric oxygen, use of oxygen in burning, formation of oxides of metals and nonmetals, rusting, uses of oxygen, extraction of sulphur (Frasch method), effect of heat on sulphur, preparation of monoclinic and plastic sulphur, preparation and properties of hydrogen sulphide, oxides of sulphur—sulphur dioxide, its laboratory preparation and properties; sulphur trioxide—its preparation and use in the manufacture of sulphuric acid by contact process.

10. Nitrogen and Phosphorus

Preparation of nitrogen in the laboratory, physical properties of nitrogen, interaction of nitrogen with hydrogen, halogens and oxygen. Ammonia—its laboratory preparation and properties, uses of ammonia and its compounds. Oxides of nitrogen—simple properties of nitric oxide and nitrogen dioxide; preparation, properties and uses of nitric acid, uses of nitrogen and its compounds—fixation of atmospheric nitrogen and nitrogen cycle; detection of nitrate ion in salts.

Occurrence of phosphorus in nature, allotropes of phosphorus, interaction of phosphorus with oxygen, chlorine, acids and alkalies, uses of phosphorus and its compounds, preparation and uses of superphosphate, detection of phosphate ion in salts.

11. Metals and Metallurgical Processes

Common characteristics of metals, simple chemical properties of Na, Ca, Mg, Al, Zn, Fe, Pb and Cu (reactions with air, hydrogen, halogens, sulphur, water and acids), industrial preparation of sodium hydroxide and sodium carbonate. Occurrence of metals in nature, extraction of iron, aluminium, copper and zinc from their ores (outlines only), simple allloys of magnesium, aluminium, zinc, copper, iron and lead.

12. Hydrogen and Water

Hydrogen—occurrence and importance, displacement of hydrogen from water and acids by metals; sources of water, hard and soft water, removal of temporary and permanent hardness of water, purification of water for drinking.

13. Solutions and Electrolytic Dissociation

Solutions, colloids and suspensions; solubility, solute and solvent, use of water as a solvent; exothermic and endothermic changes during dissolution of substances in water, concentration of solutions.

Electric conductivity of solutions, electrolysis, electrolytes and non-electrolytes, pH scale, dissociation of acids, bases and salts in water, some uses of electrolysis (electroplating, electrorefining and electrotyping).

14. Types of Chemical Changes and Rates of Reactions

Types of chemical changes (combination, decomposition, substitution, double decomposition, reversible and irreversible reaction, oxidation and reduction, oxidising and reducing agents, exothermic and endothermic reactions). Factors affecting reaction rates—nature and state of reactants, concentration, temperature, catalyst. Chemical equilibrium and Le Chatelier's principle.

15. Carbon

Occurrence of carbon in nature, structure of carbon—tetravalency, allotropic modifications of carbon properties and uses of diamond and graphite. Formation of carbon monoxide and its uses, carbon dioxide—its laboratory preparation, condition, properties and uses.

16. Fuels

Solid, liquid and gaseous fuels, energy value of fuels, combustion, conditions necessary for combustion. Fire extinguishers.

17. Compounds of Carbon (Organic Chemistry)

Hydrocarbons—introduction to saturated and unsaturated, aliphatic and aromatic hydrocarbons, homologous series, some physical and chemical properties of hydrocarbons, test for some reactive functions (alcohol, aldehyde and carboxylic acid) in organic compounds. Classification of organic compounds and their nomenclature. Elementary study of petroleum and petrochemicals.

Note : 1-10 are covered in *Revision in Chemistry*, Vol. 1. 11-17 are covered in *Revision in Chemistry*, Vol. 2.

UNIT 11

Metals and Metallurgical Processes

D.11.1 Metal: An element which forms ions by loss of electrons.

D.11.2 Non-metal: An element which forms ions by gain of electrons.

D.11.3 Metalloids: Elements which have some properties typical of metals and some typical of non-metals.

D.11.4 Metallurgy: The process of extraction of a metal from its ores.

D.11.5 Mineral: The natural material in which a metal or its compounds occur in the earth.

D.11.6 Ore: A mineral from which a metal can be profitably and conveniently extracted.

D.11.7 Gangue or Matrix: Rocky material generally accompanying ores.

D.11.8 Concentration of the ore: A process of removal of gangue from the ore.

D.11.9 Calcination: A process of heating of the concentrated ore in the absence of air.

D.11.10 Roasting: A process of heating of the concentrated ore in a stream of air.

D.11.11 Smelting: A process of extraction of a metal from its concentrated ore by reduction of oxide or sulphide of the metal with carbon in a furnace.

D.11.12 Slag: A non-metallic by-product produced during the course of smelting of the concentrated and roasted ore.

D.11.13 Flux: A substance added to assist fusion.

D.11.14 Refining: A process of purification of the metal.

D.11.15 Rust: A mixture of hydrated oxides of iron, mainly $Fe_2O_3.xH_2O$. It is formed on the surface of iron when it is exposed to moisture and air.

Q.11.1 Which properties distinguish metals from non-metals?

Answer: The main features of distinction between metals and non-metals are given in Table 11.1.

TABLE 11.1 DISTINCTION BETWEEN METALS AND NON-METALS

Metals	*Non-metals*
1. Exist as solids under normal conditions except mercury which is a liquid	Exist as solids, liquids and gases
2. Possess metallic lustre	Do not possess metallic lustre
3. Possess high density	Possess low density
4. Are good conductors of heat and electricity	Are poor conductors of heat and electricity
5. Are malleable and ductile	Are not malleable and ductile. Solids are brittle
6. Form basic oxides	Form acidic oxides
7. React with mineral acids with the evolution of a gas	Do not react with mineral acids

Q.11.2 Discuss the position of metals and non-metals in the periodic table.

Answer: In a periodic table:

(i) Mettalic character decreases and non-metallic character increases as we move from left to right in a period. Thus, in the third period, sodium is the most metallic, whereas chlorine is a typical non-metal.

(ii) Metallic character increases as we move down a group.

Thus metals occupy the left and central positions in the periodic table, whereas non-metals and inert gases occupy the right positions (Fig. 11.1). In between, there are some elements which exhibit some metallic and some non-metallic properties. They are known as metalloids(e.g. B, Si, Ge, As, Sb, etc.)

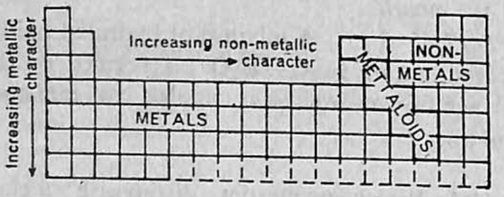

Increasing metallic character
Increasing non-metallic character
NON-METALS
METALLOIDS
METALS

FIG. 11.1 Position of metals, non-metals and metalloids in the periodic table.

Q.11.3 State some important chemical properties of metals.

Answer

(a) *Reaction with air*: When kept in air, *sodium* reacts readily to form sodium oxide. This reacts with moisture in the air to form the hydroxide. The CO_2 in the air then combines with NaOH to form a white crust of sodium carbonate.

$$4Na+O_2 \rightarrow 2Na_2O$$
$$Na_2O+H_2O \rightarrow 2NaOH$$
$$2NaOH+CO_2 \rightarrow Na_2CO_3+H_2O$$

Calcium, in contact with air, forms a thin layer of calcium oxide.

$$2Ca+O_2 \rightarrow 2CaO$$

On heating in air it burns to form calcium oxide and calcium nitride.

$$2Ca+O_2 \rightarrow 2CaO$$
$$3Ca+N_2 \rightarrow Ca_3N_2$$

Magnesium, on heating, burns in air to form the oxide and nitride.

$$2Mg+O_2 \rightarrow 2MgO$$
$$3Mg+N_2 \rightarrow Mg_3N_2$$

With moist air *aluminium* forms a thin layer of aluminium oxide over the metal, which protects it from further reaction.

$$4Al+3O_2 \rightarrow 2Al_2O_3$$

When heated in air, aluminium burns with a dazzling flame.

Zinc burns on heating in air to form zinc oxide.

$$2Zn+O_2 \rightarrow 2ZnO$$

Iron, in the presence of moist air, gets covered with a brownish red layer known as rust. Rust is a mixture of hydrated oxides of iron ($Fe_2O_3 \cdot xH_2O$).

On prolonged heating in air, iron gives the oxide.

$$3Fe+2O_2 \rightarrow Fe_3O_4$$

Lead does not react with dry air. In moist air it forms a thin layer of basic lead carbonate [$PbCO_3 \cdot Pb(OH)_2$], which protects the metal from further attack by air.

At ordinary temperatures, *copper* does not react with dry air. In moist air it gets covered by a layer of green basic copper carbonate [$CuCO_3 \cdot Cu(OH)_2$].

$$2Cu+H_2O+CO_2+O_2 \rightarrow CuCO_3 \cdot Cu(OH)_2$$

(b) *Reaction with hydrogen*: When H_2 is passed over heated Na, Ca, or Mg, hydrides are formed.

$$2Na+H_2 \rightarrow 2NaH$$
$$Ca+H_2 \rightarrow CaH_2$$
$$Mg+H_2 \rightarrow MgH_2$$

Al, Zn, Fe, Pb, Cu, etc. do not react with H_2.

(c) *Reaction with halogens*: Halogens form the corresponding halide when passed over heated metals.

$$2Na+Cl_2 \rightarrow 2NaCl$$
$$Ca+Cl_2 \rightarrow CaCl_2$$

$$Mg+Cl_2 \rightarrow MgCl_2$$
$$2Al+3Cl_2 \rightarrow 2AlCl_3$$
$$Zn+Cl_2 \rightarrow ZnCl_2$$
$$2Fe+3Cl_2 \rightarrow 2FeCl_3$$
$$Pb+Cl_2 \rightarrow PbCl_2$$
$$Cu+Cl_2 \rightarrow CuCl_2$$

(d) *Reaction with sulphur*: Most metals, on heating with sulphur, give sulphides.

$$2Na+S \rightarrow Na_2S$$
$$Ca+S \rightarrow CaS$$
$$Mg+S \rightarrow MgS$$
$$2Al+3S \rightarrow Al_2S_3$$
$$Zn+S \rightarrow ZnS$$
$$2Fe+3S \rightarrow Fe_2S_3$$
$$Pb+S \rightarrow PbS$$
$$Cu+S \rightarrow CuS$$

(e) *Reaction with water*: Sodium and potassium react violently with cold water producing a lot of heat and liberating H_2.

$$2Na+2H_2O \rightarrow 2NaOH+H_2$$
$$2K+2H_2O \rightarrow 2KOH+H_2$$

Calcium also reacts with cold water, though the reaction is not as violent as in the case of sodium.

$$Ca+2H_2O \rightarrow Ca(OH)_2+H_2$$

Magnesium, zinc and iron react only when steam is passed over heated metals, liberating hydrogen.

$$Mg+H_2O \rightarrow MgO+H_2$$
$$Zn+H_2O \rightarrow ZnO+H_2$$
$$3Fe+4H_2O \rightarrow Fe_3O_4+4H_2$$

Copper and lead do not react with water. Aluminium does not react with water due to the protective layer of its oxide on the surface.

(f) *Reaction with acids*: Sodium, magnesium, calcium, zinc, aluminium and iron react with dilute hydrochloric or sulphuric acid to displace hydrogen.

$$2Na+2HCl \rightarrow 2NaCl+H_2$$
$$Mg+2HCl \rightarrow MgCl_2+H_2$$
$$Ca+2HCl \rightarrow CaCl_2+H_2$$
$$Zn+2HCl \rightarrow ZnCl_2+H_2$$
$$2Al+6HCl \rightarrow 2AlCl_3+3H_2$$
$$2Fe+6HCl \rightarrow 2FeCl_3+3H_2$$

The reactions with H_2SO_4 are similar. Hydrogen is liberated and the respective sulphate is formed. Examples:

$$Zn+H_2SO_4 \rightarrow ZnSO_4+H_2$$
$$Fe+H_2SO_4 \rightarrow FeSO_4+H_2$$
$$2Al+3H_2SO_4 \rightarrow Al_2(SO_4)_3+3H_2$$

Copper and lead do not react with dilute acids. They, however, react with hot concentrated sulphuric acid to give sulphur dioxide.

$$Cu+2H_2SO_4 \rightarrow CuSO_4+SO_2+2H_2O$$
$$Pb+2H_2SO_4 \rightarrow PbSO_4+SO_2+2H_2O$$

(g) *Displacement reactions*: Metals ionize by losing electrons. Those which lose electrons more readily are said to be more electropositive, and are more active. They can displace less active metals from their salt solutions. The arrangement of metals which indicates their relative tendency to ionize and hence their activity, is known as the electrochemical or activity series. The order of activity among potassium, sodium, magnesium, aluminium, zinc, iron, lead, copper, gold and silver is

$$K > Na > Mg > Al > Zn > Fe > Pb > Cu > Ag > Au$$

All metals can displace other metals lower in the electrochemical series from their salt solutions. Thus when zinc is added to copper sulphate solution, copper gets deposited and zinc goes into solution.

$$Zn+CuSO_4 \rightarrow ZnSO_4+Cu$$

Similarly

$$Fe+CuSO_4 \rightarrow FeSO_4+Cu$$
$$Zn+FeSO_4 \rightarrow ZnSO_4+Fe$$

Q.11.4 Describe two major industrial methods for the manufacture of sodium hydroxide.

Answer: (i) *Electrolytic method*: Sodium hydroxide is usually manufactured by the electrolysis of a concentrated solution of brine, obtained by extraction of underground deposits of sodium chloride by pumping hot water. Various cells are in use for the electrolysis, but all depend upon the following overall cathode reaction.

$$H^+(aq)+e^- \rightarrow H(g)$$

The result of discharging $H^+(aq)$ ions is that Na^+ and OH^- ions are left behind in the cathode region.

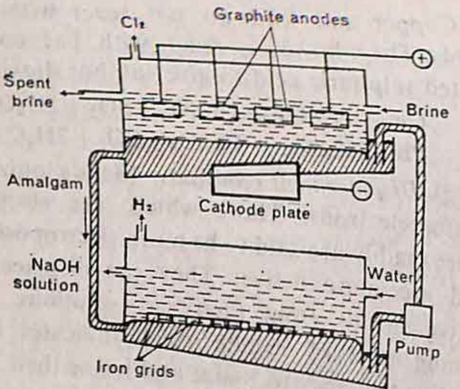


FIG. 11.2 The Castner-Kellner cell.

The *Castner-Kellner cell* (Fig. 11.2) is a popular cell employed for the manufacture of NaOH. It contains two parts—the mercury cell and the soda cell. In the upper cell, on electrolysis, chlorine is discharged at the graphite anodes and sodium at the flowing mercury cathode, where it reacts with mercury and forms a sodium amalgam.

In the lower soda cell, the amalgam is treated with water. Iron grids float on the surface of the amalgam and the amalgamated sodium reacts with water, liberating hydrogen at the surface of the iron grids and giving a solution of sodium hydroxide which is concentrated by evaporation. The liberated mercury is recycled to the upper cell. The reactions taking place are:

Cathode *Anode*

$$Na^+ \longleftarrow Na^+Cl^- \longrightarrow Cl^-$$

Cathode	*Anode*
$Na^+ + e^- \rightarrow Na$	$Cl^- - e^- \rightarrow Cl$
$Na + Hg \rightarrow \underset{\text{(amalgam)}}{Na/Hg}$	$Cl + Cl \rightarrow Cl_2$

$$2Na/Hg + 2H_2O \rightarrow 2NaOH + H_2 + 2Hg$$

(ii) *Gossage's method*: In this method milk of lime $[Ca(OH)_2]$obtained from calcium carbonate is treated with a solution of sodium carbonate in large tanks provided with mechanical stirrers. The solution is steam heated.

$$CaCO_3 \xrightarrow{\text{heat}} CaO \xrightarrow{H_2O} Ca(OH)_2$$

$$Ca(OH)_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaOH$$

Insoluble $CaCO_3$ is filtered out and the NaOH solution is concentrated by evaporation.

Q.11.5 Describe the ammonia soda (Solvay) process for the manufacture of sodium carbonate.

Answer: The industrially important compound sodium carbonate, is manufactured by the ammonia soda (also called Solvay) process (Fig. 11.3). In the ammonia absorption tower, ammonia and brine are mixed to form ammoniated brine.

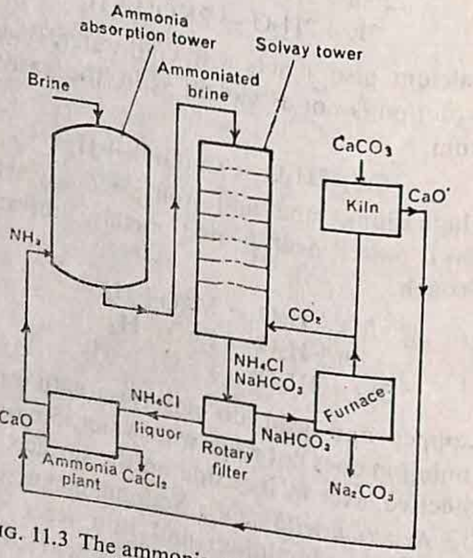


FIG. 11.3 The ammonia soda (Solvay) process for the manufacture of sodium carbonate.

Carbon dioxide is obtained by heating limestone.

$$CaCO_3 \rightarrow CaO + CO_2$$

This is then blown through the brine under pressure in the Solvay tower. This tower is fitted with perforated plates to ensure thorough mixing of CO_2 and the ammoniated brine. The following reactions take place in the tower.

$$NH_4OHl + CO \rightarrow NH_4HCO_3$$

$$NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$$

The sodium bicarbonate (less soluble in cold water) slurry is fed into the rotary vacuum filter, and the solid mass is then heated to produce Na_2CO_3.

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

CO_2 formed in this reaction is passed back to the Solvay tower.

The calcium oxide from the limestone is used in the ammonia plant to regenerate ammonia from the NH_4Cl solution.

$$CaO + 2NH_4Cl \rightarrow H_2O + 2NH_3 + CaCl_2$$

$CaCl_2$ is the by-product of the process.

Q.11.6 How do metals occur in nature? Name some important minerals from which the common metals are extracted. Also name the most common method of extraction.

Answer: Less active metals occur in the free or native state, e.g. gold and platinum. Most of the metals occur in the combined state as oxides, sulphides, carbonates and chlorides.

Table 11.2 lists the important minerals from which the common metals are extracted, and names the process involved in extraction.

Q. 11.7 What is metallurgy? Discuss briefly the methods employed for the extraction of metals from their ores.

Answer: The process of extracting a metal from its ores is called *metallurgy*.

The following metallurgical operations are carried out for isolating the metals from their ores.

(a) Dressing or concentration of the ore.
(b) Conversion of the enriched ore into metal.
(c) Purification or refining of the metal.

Dressing or concentration of the ore

The process of removal of unwanted impurities from the ore is called dressing or concentration of the ore. Cconcentration is done by the following methods.

TABLE 11.2 IMPORTANT MINERALS FOR EXTRACTION OF METALS

Metal	*Class of mineral*	*Name of mineral*	*Process*
1. Sodium	Chloride	Rock salt, $NaCl$	Electrolysis
2. Calcium	Carbonate	Dolomite, $MgCO_3, CaCO_3$	
	Sulphate	Gypsum, $CaSO_4$	
3. Aluminium	Oxide	Bauxite, $Al_2O_3 \cdot 2H_2O$	
		Corondum, Al_2O_3	
4. Zinc	Oxide	Zincite, ZnO	Reduction of oxide (Non-oxide ores are first converted to oxide)
	Sulphide	Zinc blende, ZnS	
	Carbonate	Calamine, $ZnCO_3$	
5. Iron	Oxide	Haematite, Fe_2O_3	
		Magnetite, Fe_3O_4	
		Limonite, $Fe_2O_3 \cdot 3H_2O$	
	Carbonate	Siderite, $FeCO_3$	
6. Tin	Oxide	Tinstone, SnO_2	
7. Lead	Sulphide	Galena, PbS	
8. Copper	Sulphide	Copper pyrites, $CuFeS_2$	
		Copper glance, Cu_2S	
	Oxide	Cuprite Cu_2O	
	Others	Malachite ,$Cu(OH)_2.CuCO_3$	
9. Silver	Sulphide	Argentite, Ag_2S	
10. Gold	Found in native state		

PHYSICAL METHODS

(i) *Hand-picking*: In this, lumps of rock-material are removed by hand.

(ii) *Gravity separation or hydraulic washing*: The crushed ore is agitated with water or washed in a running stream of water. The heavy ore settles down while the lighter gangue is washed away. Two common methods are employed for gravity separation.

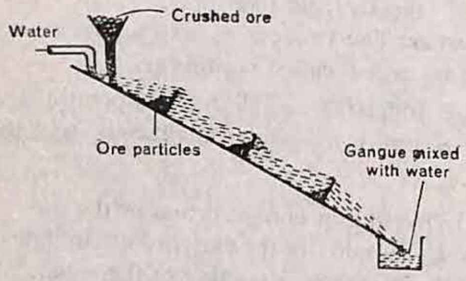


FIG. 11.4 The Wilfley table.

1. WILFLEY TABLE METHOD: The Wilfley table is a wooden sloping table fitted with wooden strips (Fig. 11.4).

Powdered ore is fed from the top and a stream of water is made to flow as shown in the diagram. The table is given a rocking motion. The heavier ore particles collect behind the wooden strips. The lighter gangue is taken away by the stream.

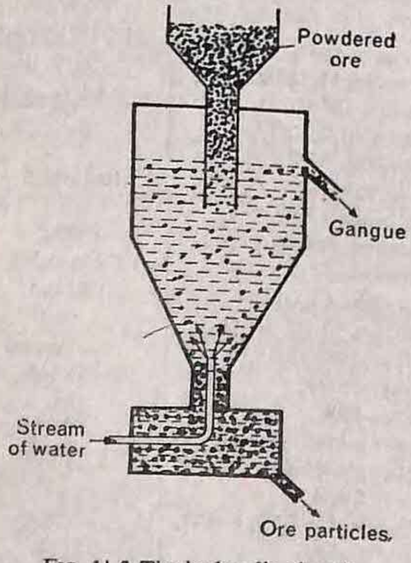


FIG. 11.5 The hydraulic classifier.

2. HYDRAULIC CLASSIFIER: Powdered ore is added from the top and a stream of water is introduced from the bottom. Lighter gangue goes out from the top while heavier ore particles collect at the bottom (Fig. 11.5).

(iii) *Magnetic concentration*: Ores which are magnetic in character are separated from non-magnetic impurities by this method. Powdered ore is dropped at one end of a belt moving over two rollers, one of which encloses a strong electromagnet. Magnetic and non-magnetic particles fall separately as shown in Fig. 11.6.

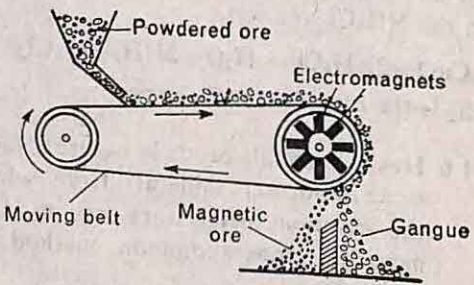


FIG. 11.6 Magnetic concentration of ore.

(iv) *Froth floatation process*: This process is generally used with sulphide ores and is based on the principle of preferential wetting of solid surfaces by various liquids. Powdered sulphide ore with water and a little pine oil is agitated with compressed air (Fig. 11.7). Oil wets the ore

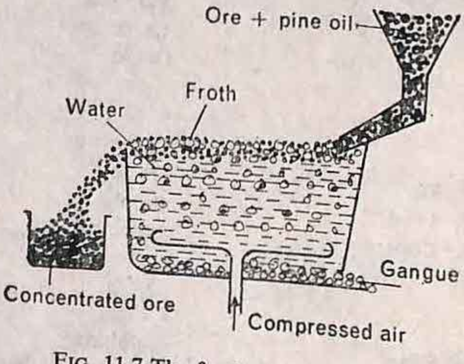


FIG. 11.7 The froth floatation process.

more readily, and the ore comes on the top in the form of a froth which is then separated.

CHEMICAL METHODS

(i) *Calcination*: It is a process of heating the ore strongly in the absence of air. Carbonate and hydrated oxide ores are generally purified by this method. In this process volatile impurities are removed and the ore becomes porous. Carbonate ores decompose to oxide and carbon dioxide is liberated.

$$ZnCO_3 \rightarrow ZnO + CO_2$$
$$Al_2CO_3 \cdot 2H_2O \rightarrow Al_2O_3 + 2H_2O + CO_2$$

(ii) *Roasting*: It is a process of heating the ore strongly in the presence of air. Sulphide ores are generally roasted. In this process the volatile impurities are removed and the ore becomes porous. The ore changes to the corresponding oxide.

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

Conversion of the enriched ore into metal

The following methods are employed.

(i) *Smelting*: It is a process of extracting a metal in the fused state. The metal is extracted by various processes. A few of them are given below :

1. USING COKE: The calcined or roasted ore is heated with coke. Free metal is obtained. This method is used for extracting iron, zinc, lead and tin.

$$ZnO + C \rightarrow Zn + CO$$
$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$

2. USING ALUMINIUM(Aluminothermic process): Oxides of certain metals, which are not reduced by coke, are reduced using aluminium powder. Manganese and chromium are extracted by this method.

$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$$

(ii) *Electrolytic reduction*: Active metals such as potassium, sodium, magnesium and calcium are extracted by electrolysis of their molten salts such as chlorides.

Refining or purification of the metal

Metals obtained by the above processes are impure and contain small amounts of impurities. The common methods used for purification are as follows.

(i) *Distillation process*: Volatile metals like mercury, zinc and cadmium are purified by this method. On heating, the volatile metal vaporises, leaving the less volatile impurities behind.

(ii) *Oxidation process*: This process is employed when impurities can be oxidized more readily than the metal. The impurities are converted into their oxides and are removed. Iron, copper and tin are purified by this method.

(iii) *Electrolytic refining*: The impure metal is made the anode and a thin plate of the pure metal is made the cathode. A solution of a metal salt is used as the electrolyte. On passing an electric current, the pure metal dissolves from the anode and is deposited on the cathode. The impurities settle at the bottom below the anode and are called anode mud (Fig. 11.8). In effect, therefore, the pure metal is transferred from the impure anode to the cathode.

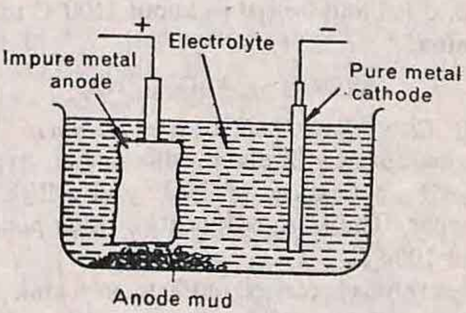


FIG. 11.8 Electrolytic refining.

Q. 11.8 Discuss the occurrence of aluminium in the earth's crust. Mention the important ores of aluminium.

Answer: Aluminium does not occur in the free state. In the combined state it is the most abundant metal in the earth's crust. The major ores of aluminium are :

(i) Bauxite ($Al_2O_3 \cdot 2\,H_2O$)
(ii) Cryolite (Na_3AlF_6)
(iii) Corondum (Al_2O_3)

Q. 11.9 Describe briefly the electrolytic method of extraction of aluminium from bauxite.

Answer: Aluminium is extracted from bauxite by first purifying it and then reducing the alumina (Al_2O_3) formed to aluminium by electrolysis.

(i) *Purification of bauxite*: Powdered and washed bauxite is dissolved in a hot concentrated solution of sodium hydroxide. Aluminium oxide dissolves to form sodium aluminate ($NaAlO_2$).

$$Al_2O_3+2NaOH \rightarrow 2NaAlO_2+H_2O$$

The impurities, iron (III) oxide and silica, being insoluble are filtered out.

The filtrate is diluted with water. The sodium aluminate gets hydrolysed to yield aluminium hydroxide.

$$NaAlO_2+2H_2O \rightarrow Al(OH)_3+NaOH$$

The precipitated aluminium hydroxide is filtered, dried and heated to about 1100°C to get alumina.

$$2Al(OH)_3 \rightarrow Al_2O_3+3H_2O$$

(ii) *Electrolytic reduction of alumina*: The alumina obtained is dissolved in molten cryolite (Na_3AlF_6, a mixture of NaF and AlF_3) and fluorspar (CaF_2) to reduce its melting point to about 1000°C.

Electrolysis is carried out in an iron tank with a graphite lining which serves as the cathode. The anodes are carbon rods dipping in the fused electrolyte (Fig. 11.9). During electrolysis, the following reactions take place.

$$AlF_3 \rightarrow Al^{3+}+3F^-$$

At the cathode $Al^{3+}+3e^- \rightarrow Al$
At the anode $F^- \rightarrow F+e^-$

$$2Al_2O_3+12F \rightarrow 4AlF_3+3O_2$$
$$C+O_2 \rightarrow CO_2$$

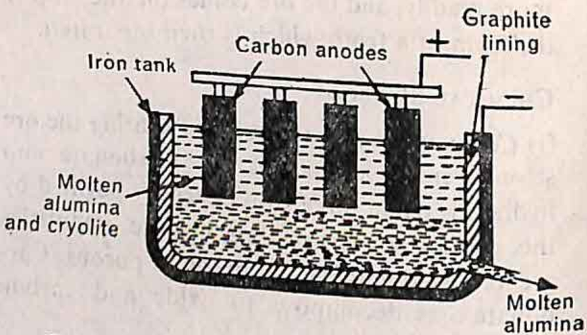


FIG. 11.9 Electrolytic reduction of alumina.

Q. 11.10 Mention some physical and chemical properties of aluminium.

Answer: *Physical* : (i) It is a silvery white metal. Its specific gravity is 2.71.

(ii) Its electronic configuration is 2, 8, 3.

(iii) It is highly malleable and ductile.

(iv) It is a good conductor of heat and electricity.

Chemical: (i) *Action with air* : It burns with a brilliant white light in air at 1073K.

$$4Al+3O_2 \rightarrow 2Al_2O_3+\text{heat}$$

At ordinary temperatures a thin layer of Al_2O_3 is formed on the surface, which protects aluminium from further corrosion.

(ii) *Action with halogens*: On passing chlorine over heated aluminium, aluminium chloride is formed.

$$2Al+3Cl_2 \rightarrow 2AlCl_3$$

(iii) *Action with nitrogen*: On heating aluminium with nitrogen, aluminium nitride is formed.

$$2Al+N_2 \rightarrow 2AlN$$

(iv) *Action with water*: Aluminium (free from protective layer of Al_2O_3) reacts with water even at ordinary temperature.

$$2Al+6H_2O \rightarrow 2Al(OH)_3+3H_2$$

(v) *Action with alkalies*: Aluminates are formed with strong alkalies at high temperature. For example,

$$2Al+2NaOH+2H_2O \rightarrow 2NaAlO_2+3H_2$$

sodium aluminate

(vi) *Action with acids*: Aluminium reacts with dilute hydrochloric or sulphuric acid to displace hydrogen.

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$$
$$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$$

Q. 11.11 How will you test aluminium ion in the laboratory?

Answer: *Lake test* : In an aluminium salt solution add a little litmus solution and excess of ammonium hydroxide. A blue gelatinous precipitate is formed which floats in a colourless medium (blue lake).

Q. 11.12 What are the uses of aluminium and of some aluminium salts?

Answer: *Uses of aluminium*: (i) As a packing material in the form of aluminium foil; (ii) In making cooking utensils; (iii) For making electrical cables; (iv) In making alloys such as duralumin, magnalium, etc.

Uses of aluminium salts : (i) Anhydrous aluminium chloride is used as a catalyst in organic synthesis.

(ii) Alumina is used in chromatography.

(iii) Potash alum is used in the purification of water, tanning of leather and as a mordant in dyeing.

Q. 11.13 How does iron occur in nature? Mention its important ores.

Answer: Iron is not found in nature in the free state. However it is abundantly found in the combined form, mainly as oxides. The important ores are:

(i) Haematite, Fe_2O_3
(ii) Magnetite, Fe_3O_4
(iii) Limonite, $Fe_2O_3 \cdot 3H_2O$
(iv) Siderite, $FeCO_3$

Q. 11.14 How is iron extracted from its ores?

Answer: (a) *Calcination*: The ore is first heated in the absence of air (calcined). This removes moisture and volatile impurities and the ore becomes porous.

(b) *Smelting*: Smelting is carried out in a blast furnace which is a tall steel structure lined with fire bricks (Fig. 11.10). A mixture of the calcined ore, coke and limestone is fed into the furnace from the top and a blast of hot air is introduced at the bottom. The following reactions take place.

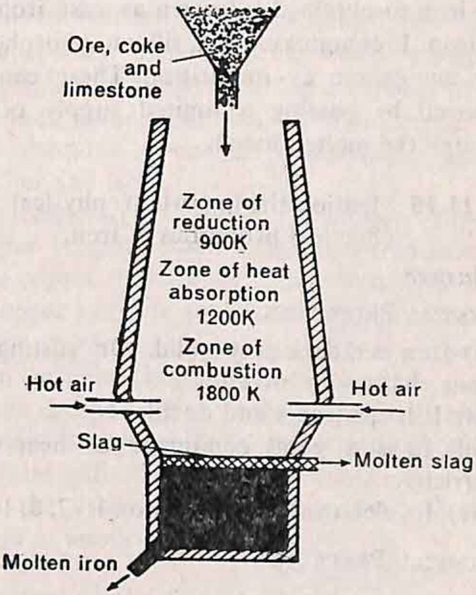


FIG. 11.10 Smelting of iron.

(i) In the lower portion (zone of combustion ~ 1800 K) coke burns to produce carbon dioxide and heat is liberated.

$$C + O_2 \rightarrow CO_2 + \text{heat}$$

(ii) As the carbon dioxide moves higher in the furnace (zone of heat absorption ~ 1200 K), the amount of air decreases and the gas reacts with coke to give carbon monoxide.

$$CO_2 + C \rightarrow 2CO - \text{heat}$$

(iii) At the top portion of the furnace (zone of reduction ~ 900 K) carbon monoxide reduces the oxide of iron to metallic iron.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

Molten iron passes on to the bottom of the furnace.

(iv) In the same zone, limestone decomposes to give calcium oxide which reacts with silica, the main impurity present in the ore, forming calcium silicate. This, along with other impurities, forms molten slag which floats above the molten iron.

$$CaCO_3 \rightarrow CaO + CO_2$$
$$SiO_2 + CaO \rightarrow CaSiO_3$$

Molten iron and slag are separately topped out. The iron so obtained is known as cast iron or pig iron. It contains carbon, silicon, phosphorus and manganese as impurities. These can be removed by passing a limited supply of air through the molten metal.

Q. 11.15 Mention the important physical and chemical properties of iron.

Answer

PHYSICAL PROPERTIES

(i) Iron is a dark grey solid. On rusting its colour changes to brown.

(ii) It is malleable and ductile.

(iii) It is a good conductor of heat and electricity.

(iv) Its electronic configuration is 2, 8, 14, 2.

CHEMICAL PROPERTIES

(i) *Action with air*: Iron, in the presence of moist air, gets covered with a brownish red layer known as rust. Rust is a mixture of hydrated oxides of iron ($Fe_2O_3 \cdot xH_2O$).

On prolonged heating in air, iron gives the oxide.

$$3Fe + 2O_2 \rightarrow Fe_3O_4$$

(ii) *Action with chlorine*: On heating with chlorine, the chloride is formed.

$$2Fe + 3Cl_2 \rightarrow 2FeCl_3$$

(iii) *Action with sulphur*: On heating with sulphur, the sulphide is formed.

$$Fe + S \rightarrow FeS$$

(iv) *Action with water*: When steam is passed over red hot iron, hydrogen is liberated.

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$$

(v) *Action with acids*: With dilute hydrochloric and sulphuric acids, iron displaces hydrogen.

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$
$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$

With dilute nitric acid, it gives ferrous nitrate and ammonium nitrate.

$$4Fe + 10HNO_3 \rightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$$

(vi) *Displacement reactions*: Iron displaces metals lower in the electrochemical series from their salts.

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

Q. 11.16 How does copper occur in nature? Outline the procedure used in the extraction of copper from copper pyrites.

Answer: The important ores of copper are:

(i) Copper glance, Cu_2S

(ii) Copper pyrites, $CuFeS_2$

(iii) Cuprite, Cu_2O

(iv) Malachite, $Cu(OH)_2.CuCO_3$

A small quantity of copper also occurs in the native state.

The following steps are involved in the extraction of copper from copper pyrites, its most important ore.

(i) *Concentration of the ore*: Powdered copper pyrites is concentrated by the froth floatation method.

(ii) *Roasting*: The ore is now heated in excess of air. Volatile impurities such as sulphur, antimony and arsenic are removed in the process. The ore is converted to a mixture of cuprous and ferrous sulphides, which in turn get partially oxidized.

$$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$
$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$
$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$

(iii) *Smelting*: The roasted ore is heated in a blast furnace (Fig. 11.11) in the presence of coke and sand. Ferrous oxide combines with sand to form fusible slag which is removed, leaving a molten mixture of cuprous sulphide and unchanged ferrous sulphide. This molten mixture is called *matte*.

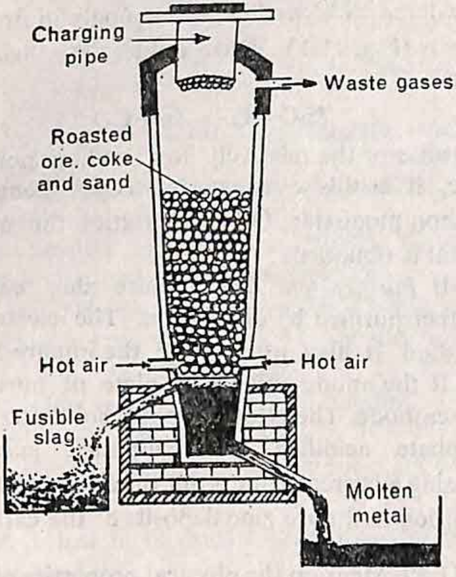


FIG. 11.11 Smelting of copper.

(iv) *Bessemerization*: The matte is now transferred to a Bessemer converter, which is a special type of blast furnance (Fig. 11.12).

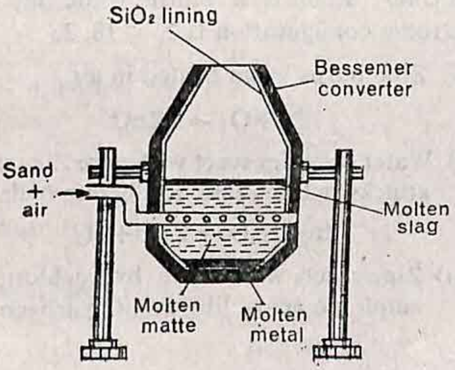


FIG. 11.12 Bessemerization of copper.

Sand is added and a blast of air is sent through the matte. Ferrous sulphide gets oxidized to ferrous oxide which combines with silica to form fusible slag.

$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$
$$FeO + SiO_2 \rightarrow FeSiO_3 \text{ (slag)}$$

Slag floats at the top of the molten mass and is periodically removed.

The cuprous sulphide is oxidised to cuprous oxide which again reacts with cuprous sulphide to give copper.

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$
$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

The molten metal is transferred into sand moulds where it solidifies. The escaping sulphur dioxide forms 'blisters' on the copper surface, and the product is known as *blister copper*. It still contains about 2% impurities, mainly sulphur and iron.

(v) *Electrolytic refining of copper*: Impure copper is made the anode and a thin sheet of pure copper the cathode in an electrolytic bath of copper sulphate acidified with sulphuric acid. When a current is passed, copper dissolves from the anode and pure copper is deposited on the cathode. Thus, in this process, there is a transfer of copper from the impure anode to the pure cathode. The impurities either pass into the solution or are deposited near the anode as anode mud.

Q. 11.17 State some important physical and chemical properties of copper.

Answer

PHYSICAL PROPERTIES

(i) Copper is a reddish metal.

(ii) It is an excellent conductor of heat and electricity.

(iii) It is highly malleable and ductile.

(iv) Its electronic configuration is 2, 8, 17,2.

CHEMICAL PROPERTIES

(i) *Action with air*: At ordinary temperatures, copper does not react with dry air. In moist air it gets covered by a layer of green basic copper carbonate $[CuCO_3 \cdot Cu(OH)_2]$.

$$2Cu + H_2O + CO_2 + O_2 \rightarrow CuCO_3 \cdot Cu(OH)_2$$

(ii) *Reaction with chlorine*: Copper reacts with chlorine directly on heating giving the chloride.

$$Cu + Cl_2 \rightarrow CuCl_2$$

(iii) *Reaction with sulphur*: On heating with sulphur, copper gives the sulphide.

$$Cu+S \rightarrow CuS$$

(iv) *Reaction with acids*: Copper does not react with dilute hydrochloric or sulphuric acids. With concentrated sulphuric acid, sulphur dioxide is liberated.

$$Cu+2H_2SO_4 \rightarrow CuSO_4+SO_2+2H_2O$$

Copper reacts with dilute and concentrated nitric acid.

$$3Cu+\underset{\text{(dilute)}}{8HNO_3} \rightarrow 3Cu(NO_3)_2+4H_2O+2NO$$

$$Cu+\underset{\text{(conc.)}}{4HNO_3} \rightarrow Cu(NO_3)_2+2H_2O+2NO_2$$

Q. 11.18 Name the important ores of zinc. Outline the method of extraction of zinc.

Answer: The important ores of zinc are:

(i) Zinc blende, ZnS
(ii) Calamine, $ZnCO_3$
(iii) Zincite, ZnO

The following processes are involved in the extraction of zinc from zinc blende.

(a) *Concentration*: The ore is powdered and concentrated by the froth floatation method.

(b) *Roasting*: The concentrated ore is heated with excess of air. Zinc blende is oxidised to zinc oxide.

$$2ZnS+3O_2 \rightarrow 2ZnO+2SO_2$$

If calamine is used, it decomposes to zinc oxide on heating.

$$ZnCO_3 \rightarrow ZnO+CO_2$$

(c) *Reduction*: Zinc oxide is mixed with powdered coke and heated strongly in fire-clay retorts (Fig. 11.13). Coke reduces the oxide to zinc.

$$ZnO+C \rightarrow Zn+CO$$

Because of the relatively low boiling point of zinc, it distills over as it is formed, along with carbon monoxide. On condensation the molten metal is obtained.

(d) *Purification*: The impure zinc can be further purified by distillation. The electrolytic method is also used. Here the impure zinc is made the anode and a thin plate of pure zinc the cathode. The electrolyte is a solution of zinc sulphate acidified with sulphuric acid. On passing a current, zinc from the anode goes into solution and pure zinc deposits at the cathode.

Q.11.19 Mention the physical properties of zinc. How does zinc react with the following: (i) air, (ii) water, (iii) acids, (iv) halogens, (v) sulphur, hydrogen, and nitrogen, (vi) alkalies.

Answer: Zinc is a bluish white metal. Its electronic configuration is 2, 8, 18, 2.

(i) Zinc burns when heated in air.

$$2Zn+O_2 \rightarrow 2ZnO$$

(ii) Water does not react with pure Zinc. Steam attacks red hot zinc, to liberate hydrogen.

$$Zn+H_2O \rightarrow ZnO+H_2$$

(iii) Zinc reacts with dilute hydrochloric and sulphuric acids, liberating hydrogen.

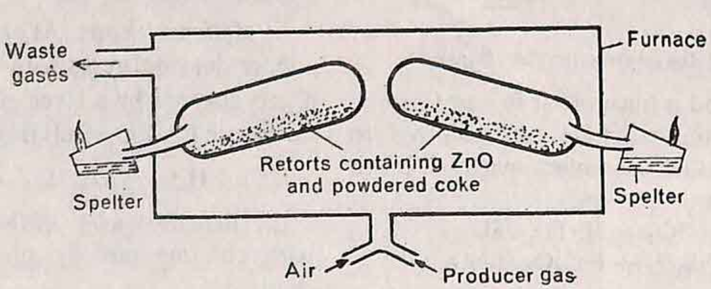


Fig. 11.13 Reduction of zinc oxide to zinc.

$$\mathrm{Zn+2HCl \rightarrow ZnCl_2+H_2}$$

$$\mathrm{Zn+H_2SO_4 \rightarrow ZnSO_4+H_2}$$

Nitric acids also attacks zinc.

$$\mathrm{4Zn+\underset{(dilute)}{10HNO_3} \rightarrow 4Zn(NO_3)_2+N_2O+5H_2O}$$

$$\mathrm{4Zn+\underset{(very\ dilute)}{10HNO_3} \rightarrow 4Zn(NO_3)_2+NH_4NO_3+3H_2O}$$

$$\mathrm{Zn+\underset{(conc.)}{4HNO_3} \rightarrow Zn(NO_3)_2+2H_2O+2NO_2}$$

Concentrated sulphuric acid attacks zinc on heating and sulphur dioxide is liberated.

$$\mathrm{Zn+2H_2SO_4 \rightarrow ZnSO_4+2H_2O+SO_2}$$

(iv) Chlorine reacts with zinc on heating.

$$\mathrm{Zn+Cl_2 \rightarrow ZnCl_2}$$

(v) Sulphur reacts with zinc on heating.

$$\mathrm{Zn+S \rightarrow ZnS}$$

Both hydrogen and nitrogen do not react with zinc.

(vi) A solution of caustic soda dissolves zinc on heating.

$$\mathrm{Zn+2NaOH \rightarrow \underset{sodium\ zincate}{Na_2ZnO_2}+H_2}$$

Q.11.20 What is an alloy? Discuss, giving examples, the importance of alloys.

Answer: An alloy is a mixture of two or more metals or one or more metals and a non-metal. The process of alloying is used to alter the properties of a metal to suit certain applications. Alloys are made to either improve the colour and hardness of metals or to protect them from corrosion. For example, pure gold is a very soft metal and cannot be used to make jewellery. When alloyed with copper it becomes hard and tough, and can then be easily used. Even pure iron is a weak metal, which can be made very strong by alloying it with carbon, chromium, etc. to form steel. The process of alloying therefore has immense industrial applications.

Q.11.21 List the important alloys of aluminium, copper, iron and lead. Give their composition, properties and uses.

Answer: See Table 11.3.

TABLE 11.3 ALLOYS AND THEIR USES

Name of alloy 1	*Composition* 2	*Properties* 3	*Uses* 4
Alloys of Aluminium			
Duralumin	Al 95% Cu 4% Mg 0.5% Mn 0.5%	Lightweight, hard, strong, resistant to corrosion	Aircraft bodies and ships
Magnalium	Al 70-95% Mg 30-5%	Lightweight, hard, strong	Household appliances
Alloys of Copper			
Brass	Cu 60-90% Zn 40-10%	Harder and stronger than Cu. Easily machined	Electrical goods, utensils, cartridge caps
Bronze	Cu 88-96% Sn 12-4%	Tough and hard	Statues, coins, utensils
Phosphor bronze	Cu 95% Sn 4.8% P 0.2%	Highly corrosion resistant	Spring wires, suspension filaments for electrical instruments
German silver	Cu 25-50% Ni 10-35% Zn 10-35%	Silvery appearance Resistant to corrosion	Utensils, resistance wires
Gun metal	Cu 88% Sn 10% Zn 2%		Part of guns, gears, bearings

15349

1	2	3	4
Aluminium bronze	Cu 81-90% Al 7-12% Sn 0-0.5%	Golden yellow in colour	Imitation jewellery, coins, paints
Alloys of Iron			
Steel	Fe 99% C 1%	Hard, durable	Buildings, furniture, railway lines
Stainless steel	Fe 73% Cr 1% C 8% Ni 18%	Corrosion resistant	Utensils, cycle and automobile parts, storage tanks
Manganese steel	Fe 84-87% Mn 15-12% C 1%	Very hard, corrosion resistant, high melting point	Railway lines, heavy machinery
Tungsten steel	Fe 71-82% W 14-20% Cr 3-8% C 0.5-1%	Very hard even at red heat, strong	High speed tools, drill bits
Invar	Fe 63% Ni 36% C 1%	Very low expansion on heating	Pendulums, measuring tapes
Alnico	Fe 63% Al 12% Ni 20% Co 5%	Highly magnetic	Permanent magnets
Alloys of Lead			
Solder	Pb 50% Sn 50%	Low melting point but hard when solid	For soldering
Type metal	Pb 70% Sn 10% Sb 18 % Cu 2%	Expands on solidification	Making types used in printing process

EXERCISES

11.1 (a) What happens when Al and Zn are treated with HCl and NaOH?

(b) Name two metals which occur in nature in the native state.

11.2 Name two metals which are obtained by the reduction of their oxides by carbon. Give chemical equations involved in their extractions.

11.3 Explain the following:

(i) Aluminium reacts with air both at ordinary and elevated temperatures.

(ii) Aluminium oxide (Al_2O_3 is amphoteric in nature.

(iii) In the extraction of metals from their oxides different reducing agents are employed, e.g. carbon and aluminium.

(iv) Metals react under different conditions with water.

(v) In the extraction of aluminium from bauxite, CaF_2 is also used.

(vi) For the detection of aluminium, the test employed is called 'lake test'.

(vii) Alloys are generally more useful and harder than metals.

11.4 Which of the two metals in each of the following reactions is more reactive.

(i) $Fe_2O_3+2Al \rightarrow Al_2O_3+2Fe$

(ii) $CuO+Mg \rightarrow MgO+Cu$

(iii) $Zn+CuSO_4 \rightarrow ZnSO_4+Cu$

(iv) $Zn+Pb(CH_3COO)_2 \rightarrow Zn(CH_3COO)_2+Pb$

Which characteristic property of metals makes them more reactive?

[*Hint*: (i) Al (ii) Mg (iii) Zn (iv) Zn.
Tendency to lose electrons. Greater the tendency of the metal to lose electrons the more reactive it is.]

11.5 Which one of the following properties would you not expect copper to exhibit?

(i) High thermal conductivity.
(ii) Low electrical conductivity.
(iii) Lustre.
(iv) Ductility.
(v) Malleability.

[*Hint*: (ii), due to high electrical conductivity of copper]

11.6 Fill in the blanks in the following.

(i) A mineral from which a metal can be profitably produced is called an......
(ii) In electrolytic refining the pure metal sheet is used as.........
(iii) In electrolytic refining pure metal is deposited on the.........
(iv) Oxide and carbonate ores are usually concentrated by.........and.........
(v) Aluminium belongs to group.........and iron belongs to group.........of the periodic table.
(vi) Hardness of steel is adjusted by.........
(vii) ....is the metal which is used in galvanizing iron to protect it from.........

[*Hint*: (i) Ore (ii) Cathode (iii) Cathode (iv) Gravity process, Froth floatation process (v) III, VIII (vi) Tempering (vii) Zinc, Rusting.]

11.7 Match the descriptions given in column B against the statements/terms under column A.

COLUMN A

(i) Calcination
(ii) Roasting
(iii) Froth floatation process
(iv) Bauxite
(v) Bronze
(vi) Nelson's cell
(vii) Flux
(viii) Invar

COLUMN B

(i) A process of converting ore into oxide in the presence of air.
(ii) An alloy of Cu and Zn.
(iii) A process of converting ore into oxide in the absence of air.
(iv) An ore of aluminium.
(v) A process of concentrating sulphide ores.
(vi) Used for the manufacture of sodium hydroxide.
(vii) An alloy of nickel and iron with a small amount of carbon.
(viii) Helps in removing impurities.

11.8 Underline the appropriate answer.

(i) A blast furnace is used in the extraction of
(a) aluminium (b) zinc (c) iron (d) mercury.
(ii) Roasting of an ore means heating of an ore
(a) in a limited supply of air.
(b) in excess of air.
(c) in the absence of air.
(d) in the presence of coke.
(iii) Which of the following statements is wrong?
(a) Carbon monoxide is an effecting reducing agent.
(b) Refining of a metal is always required.
(c) Froth floatation method is employed for the concentration of sulphide ores.
(d) Zinc is extracted by electro-reduction technique.
(iv) Which of the following minerals/ores is not an oxide?
(a) copper pyrites (b) bauxite (c) haematite (d) cuprite.
(v) Which of the following metals is extracted by smelting?
(a) sodium (b) magnesium (c) copper (d) aluminium.
(vi) Which of the following methods is involved in the purification of copper?
(a) distillation (b) oxidation (c) electrolytic refining (d) distribution.
(vii) Which of the following operations involve both reduction and refining?
(a) thermal decomposition (b) electrolytic reduction (c) bessemerization (d) smelting.
(viii) Which of the following alloys is an alloy of aluminium?
(a) invar (b) magnalium (c) bronze (d) gun metal.

11.9 What types of ores are roasted? Write a chemical equation for the roasting of an ore of each type. Why is this procedure used?
(*Hint*: Refer to Q. 11.7)

11.10 Describe the following metallurgical processes.
(a) Froth floatation (b) Calcination (c) Electrolytic refining (d) Magnetic concentration.
(*Hint*: Refer to Q. 11.7)

11.11 (a) Define the following.
(i) Ore (ii) Gangue (iii) Alum (iv) Smelting.
(b) Describe, with equations, the steps involved in the extraction of aluminium from bauxite.

11.12 (a) Explain the concentration of sulphide ores by froth floatation method.
(*Hint*: Refer to Q. 11.7)
(b) Compare metals with non-metals with regard to (i) number of valence electrons, (ii) acidic or basic nature of oxides, and (iii) acceptor or donor properties of elements.

11.13 Give a few properties of aluminium which make it industrially important.
[*Hint*: light metal, good conductor of heat and electricity, strong affinity for oxygen even at ordinary temperature, corrosion resistant due to Al_2O_3 layer.]

11.14 How will you obtain:
(i) Iron from Fe_2O_3.
(ii) Copper from copper pyrites.
(iii) Zin from zinc blende.
Give chemical equations in each case.

UNIT 12

Hydrogen and Water

Hydrogen is the first element in the periodic table (Fig. 12.1). It is the lightest element. An atom of hydrogen has one proton and one electron.

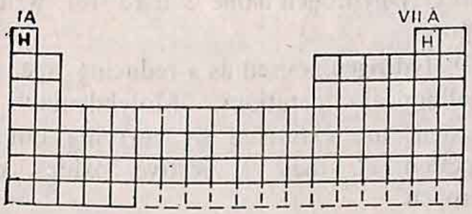


FIG. 12.1

Water is the most abundant compound in nature. The various sources of water in nature are: (i) rain water (ii) river water (iii) sea water (iv) spring water. Water is said to be hard if it does not readily give a permanent lather with soap. The presence of some soluble salts of calcium and magnesium in water is the cause of hard water. Presence of bicarbonates of calcium and magnesium causes temporary hardness. This can be removed by boiling, adding lime, etc. Permanent hardness in water is due to the presence of chlorides and sulphates of calcium and magnesium. Permutit process, Calgon process, etc. are used to remove this type of hardness. Drinking water should be free from (i) suspended impurities (ii) harmful bacteria (iii) impurites which are injurious in nature. Various methods are employed for the purification of water for drinking purposes. They are: (i) filtration (ii) sedimentation and coagulation (iii) chlorination.

D.12.1 Soft water: Water which readily gives lather with soap.

D.12.2 Hard water: Water which does not readily give lather with soap.

D.12.3 Temporary hardness: Presence of bicarbonates of calcium and magnesium in water causes temporary hardness which can be removed by boiling.

D.12.4 Permanent hardness: Caused by chlorides and sulphates of magnesium and calcium. This cannot be removed by boiling.

D.12.5 Clark's method: A method of removing temporary hardness of water by addition of slaked lime.

D.12.6 Permutit process: A process of removing permanent hardness of water by exchanging the Ca^{2+} and Mg^{2+} ions with Na^{+} ions.

D.12.7 Calgon process: A process of removing permanent hardness of water by the addition of sodium hexametaphosphate, which forms soluble complexes with calcium and magnesium ions.

D.12.8 Chlorination: Sterilization of water by addition of chlorine or bleaching powder.

Q.12.1 How does hydrogen occur in nature?

Answer: Hydrogen, because of its reactivity, is rarely found in the free state. However, in the combined form, it constitutes about 1 per cent of the crust of the earth. The most important compound of hydrogen is water which contains 11 per cent by weight of hydrogen. Hydrogen is present in all acids and bases. It is a constituent of carbohydrates, proteins, fats and oils. Most of the fuels such as wood, coal, coke, cooking gas, petrol, etc. also contain hydrogen as a major constituent.

Q.12.2 Describe the laboratory preparation of hydrogen.

Answer: Hydrogen is prepared in the laboratory by the action of dilute hydrochloric acid on granulated zinc. The gas is collected by the downward displacement of water. The apparatus is as shown in Fig. 12.2.

$$Zn+2HCl \rightarrow ZnCl_2+H_2\uparrow$$

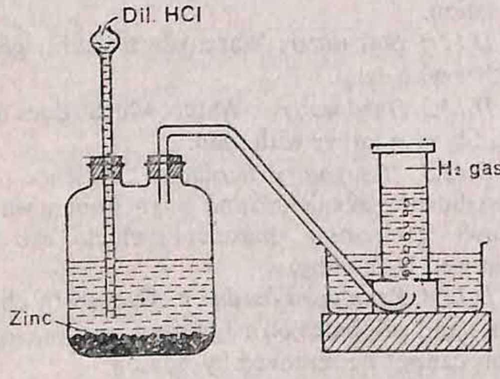


FIG. 12.2 Laboratory preparation of hydrogen.

To remove any trace of acid, the gas is passed through KOH and then through P_2O_5 to remove the moisture. Thus pure and dry hydrogen gas is obtained.

Q.12.3 Describe the important uses of hydrogen.

Answer: (1) Since hydrogen is the lightest gas, it has been used since long for inflating balloons and air ships. (However, on account of its highly inflammable nature, it has now been replaced by helium.)

(2) It is used in the manufacture of ammonia by the Haber's process.

$$N_2+3H_2 \xrightarrow[200\text{ atm}]{460\text{-}500\ ^\circ C} 2NH_3$$

(3) It is used in the manufacture of *vanaspati ghee*. This is done by hydrogenation of vegetable oils.

$$\text{vegetable oil}+H_2 \xrightarrow[5\text{ atm}]{Ni,\ 170\ ^\circ C} \text{vanaspati ghee}$$

(4) Hydrogen is used in the manufacture of petrol. This is done by hydrogenation of coal or coke at a moderately high temperature and under a very high pressure.

(5) Hydrogen is used in the manfacture of synthetic methanol.

$$CO+2H_2 \xrightarrow[450^\circ C,\ 200\text{ atm}]{ZnO+Cr_2O_3} CH_3OH$$

(6) Oxy-hydrogen flame is used for welding purposes.

(7) Hydrogen is used as a reducing agent in metallurgical operations. Molybdenum and tungsten are extracted by carrying out the reduction of their respective oxides with hydrogen.

$$MoO_3+3H_2 \xrightarrow{\text{heat}} Mo+3H_2O$$

$$WO_3+3H_2 \xrightarrow{\text{heat}} W+3H_2O$$

Q. 12.4 How is hydrogen obtained from (i) cold water (ii) steam (ii) acids (iv) caustic soda.

Answer: (i) *From cold water* : Alkali metals like sodium and potassium attack cold water very vigorously, with the evolution of hydrogen gas.

$$2Na+2H_2O \longrightarrow 2NaOH+H_2$$

Alkaline earth metals like Mg, Ca, etc. react with cold water slowly. In this case also, hydrogen is produced.

$$Mg+H_2O \longrightarrow MgO+H_2$$

(ii) *From steam*: Metals like zinc, iron, etc. decompose steam. Iron decomposes superheated steam.

$$Zn+H_2O \longrightarrow ZnO+H_2$$
$$3Fe+4H_2O \longrightarrow Fe_3O_4+4H_2$$

(iii) *From sulphuric, hydrochloric and nitric acids*: Metals like Mg, Al, Zn, Fe, decompose dilute sulphuric and hydrochloric acids with the evolution of hydrogen gas.

$$Fe+H_2SO_4 \longrightarrow FeSO_4+H_2$$
$$Zn+2HCl \longrightarrow ZnCl_2+H_2$$

Tin can react with concentrated hydrochloric acid to produce hydrogen.

$$Sn+2HCl \longrightarrow SnCl_2+H_2$$

Mg and Mn react with very dilute nitric acid to liberate hydrogen.

$$Mg+2HNO_3 \longrightarrow Mg(NO_3)_2+H_2$$

(iv) *From caustic soda*: Hot solutions of strong alkalies are decomposed by metals like Al, Zn and Sn with the evolution of hydrogen.

$$2Al+2NaOH+2H_2O \longrightarrow \underset{\text{sodium aluminate}}{2NaAlO_2}+3H_2$$

$$Zn+2NaOH = \underset{\text{sodium zincate}}{Na_2ZnO_2}+H_2$$

Q. 12.5 Give the physical and chemical properties of hydrogen.

Answer

PHYSICAL PROPERTIES

Hydrogen is a colourless and odourless gas slightly soluble in water. It is the lightest known gas.

Its melting point is 14 K and boiling point is 19.3 K. It has a density of 0.071 g/cm^3.

CHEMICAL PROPERTIES

(a) Hydrogen burns in air producing water.

$$2H_2+O_2 \longrightarrow 2H_2O$$

(b) Metals such as Li, Na, K, Ca react with hydrogen forming hydrides.

$$2Na+H_2 \longrightarrow 2NaH$$
$$Ca+H_2 \longrightarrow CaH_2$$

(c) Non-metals such as S, N_2, C, etc. react with hydrogen.

$$H_2+S \longrightarrow H_2S$$
$$3H_2+N_2 \longrightarrow 2NH_3$$
$$C+2H_2 \longrightarrow CH_4$$

(d) Halogens react with hydrogen forming halides.

$$H_2+X \longrightarrow 2HX \qquad X=Cl, Br, I$$

(e) Hydrogen reduces oxides of Cu, Pb, etc. to their metallic forms.

$$CuO+H_2 \longrightarrow Cu+H_2O$$
$$PbO+H_2 \longrightarrow Pb+H_2O$$

Q. 12.6 Describe the various sources of water in nature.

Answer: The various sources of water in nature are : (1) rain water (2) river water (3) spring water (4) sea water.

(1) *Rain water*: Rain water is obtained as a result of evaporation from the surface of the sea. Rain water is considered to be the purest of all natural waters. First showers of rain are always impure because they contain impurities present in the atmosphere such as CO_2, NH_3, dust, bacteria, germs, etc.

(2) *River water*: Rain and melting of snow in high mountains are the origin of river water. This water flows down the hills and then through plains to ultimately fall into the sea. During its flow it dissolves large quantities of mineral salts such as chlorides, sulphates, carbonates, bicarbonates of sodium, potassium, magnesium, calcium, etc. It contains some suspended particles also.

(3) *Spring water*: Some part of rain water is absorbed by the earth, goes deep and is stopped by impervious rock. If some cracks are available in the earth's surface, this water gushes out as spring water. Spring water is free from suspended organic impurities. The water stored underground can be taken out by digging deep into the earth. Water taken out in this way is known as well water. Some dissolved impurities in spring water often cause medicinal qualities. Such springs are called mineral springs and their waters are named mineral waters.

(4) *Sea water*: Sea water is very impure. It contains about 2.6 per cent of common salt and about 1 per cent of other salts of calcium, magnesium, etc. dissolved in it. The main source of these impurities are the rivers which fall into the sea.

Q. 12.7 Give important physical and chemical properties of water.

Answer

PHYSICAL PROPERTIES

1. Pure water is a colourless liquid, having no smell.
2. Water freezes at 0°C and boils at 100°C.
3. The density of water at 0°C is 0.9998 g/ml whereas the density of ice at 0°C is 0.917 g/ml, i.e. ice is lighter than water.
4. Heat of fusion of water is 80 cal/g and heat of vaporization is 540 cal/g.

CHEMICAL PROPERTIES

1. Water is neutral to litmus.
2. Pure water is a poor conductor of electricity.
3. Water is decomposed by metals. Sodium and potassium decompose water at ordinary temperature; magnesium and zinc at higher temperatures. Hot iron, aluminium, etc. react with steam.

$$2Na+2H_2O \longrightarrow 2NaOH+H_2$$
$$Mg+H_2O \longrightarrow MgO+H_2$$
$$3Fe+4H_2O \longrightarrow Fe_3O_4+4H_2$$

4. When steam is passed over red hot coke, water gas, a mixture of CO and H_2 is obtained.

$$\underset{\text{steam}}{C+H_2O} \longrightarrow \underset{\text{water gas}}{CO+H_2}$$

5. With acidic and basic oxides, water forms acids and bases.

$$CO_2+H_2O \longrightarrow H_2CO_3 \text{ (carbonic acid)}$$
$$SO_3+H_2O \longrightarrow H_2SO_4 \text{ (sulphuric acid)}$$
$$CaO+H_2O \longrightarrow Ca(OH)_2$$
$$MgO+H_2O \rightarrow Mg(OH)_2$$

6. Calcium carbide reacts with water to form acetylene.

$$CaC_2+2H_2O \longrightarrow Ca(OH)_2+C_2H_2$$

Q. 12.8 What are hard and soft waters? How could you distinguish between temporary and permanent hard water? What are the disadvantages of using hard water?

Answer: Water which does not readily produce lather with soap is described as hard water and water which does readily produce lather with soap is described as soft water.

Hardness of water is caused by the presence of soluble salts of calcium and magnesium. These ions (Ca^{2+} or Mg^{2+}) form precipitates with soap and so no lather is produced until all the calcium and magnesium compounds have been acted upon by soap.

$$\underset{\text{soap}}{2C_{17}H_{35}COONa}+Ca(HCO_3)_2$$
$$\longrightarrow \underset{\text{(precipitate)}}{(C_{17}H_{35}COO)_2Ca}+2NaHCO_3$$

$$\underset{\text{soap}}{2C_{17}H_{35}COONa}+MgCl_2$$
$$\longrightarrow \underset{\text{(precipitate)}}{(C_{17}H_{35}COO)_2Mg}+2NaCl$$

Hardness of water is of two types :

(1) Temporary hardness (2) Permanent hardness.

Temporary hardness: Hardness which is due to the presence of bicarbonates of calcium and magnesium is called temporary hardness. This type of hardness can be easily removed by boiling.

$$Ca(HCO_3)_2 \xrightarrow[\text{heat}]{\text{heat}} CaCO_3+CO_2+H_2O$$
$$Mg(HCO_3)_2 \longrightarrow MgCO_3+CO_2+H_2O$$

The insoluble carbonates are removed by filtration or sedimentation.

Permanent hardness: This type of hardness of water is due to the presence of sulphates and chlorides of calcium and magnesium. This hardness cannot be removed by boiling. The disadvantages of using hard water are as follows.

(1) More soap is consumed while washing with hard water. This is because initially some soap is used to precipitate Ca^{2+} and Mg^{2+} ions.

(2) When hard water is used in boilers, calcium and magnesium salts are deposited in the boiler tubes. Since these salts are bad conductors it causes loss of fuel and also leads to weakening of the tubes.

Q. 12.9 What are the causes of hardness? Describe briefly the methods employed for the removal of hardness of water.

Answer: For causes of hardness of water see Q. 12.8.

Temporary hardness of water can be removed by the following methods.

(i) *Boiling*: See Q. 12.8.

(ii) *Clark's method*: Slaked lime [$Ca(OH)_2$] is added to temporary hard water and heated. Insoluble carbonates are formed which are removed by filtration.

$$Ca(OH)_2 + Ca(HCO_3)_2 \longrightarrow 2CaCO_3 + 2H_2O$$
$$Ca(OH)_2 + Mg(HCO_3)_2 \longrightarrow CaCO_3 + MgCO_3 + 2H_2O$$

Permanent hardness of water is due to the presence of chlorides and sulphates of calcium and magnesium, and can be removed by the following methods.

(i) *Washing soda method*: Adding washing soda to hard water and then heating causes precipitation of insoluble calcium and magnesium carbonates, which can be removed by filtration.

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4$$
$$MgCl_2 + Na_2CO_3 \longrightarrow MgCO_3 + 2NaCl$$

(ii) *Permutit process* (*Ion exchange method*): In this method Ca^{2+} or Mg^{2+} ions, which are responsible for the hardness of water, are exchanged with Na^+ ions in the permutit. Permutit is sodium aluminium silicate, $Na_2Al_2Si_2O_8 \cdot x\,H_2O$ and is abbreviated as Na_2Z where Z stands for $Al_2Si_2O_8 \cdot x\,H_2O$

The permutit is placed in a suitable container and hard water is allowed to pass through it (Fig. 12.3). As a result, calcium and magnesium ions are exchanged with sodium ions in the permutit.

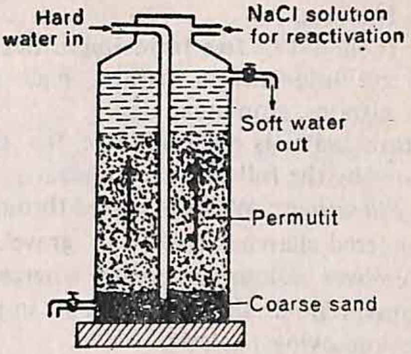


FIG. 12.3 The permutit process.

$$Na_2Z + CaCl_2 \longrightarrow CaZ + 2NaCl$$
$$Na_2Z + MgCl_2 \longrightarrow MgZ + 2NaCl$$

The water coming out of the tank is free from calcium and magnesium ions and is soft.

After using this apparatus for some time, all the sodium ions are replaced and the permutit becomes unfit for further use. It is reactivated by passing through it a 10% solution of sodium chloride.

$$CaZ + 2NaCl \longrightarrow CaCl_2 + Na_2Z$$
$$MgZ + 2NaCl \longrightarrow MgCl_2 + Na_2Z$$

Calcium chloride and magnesium chloride produced are washed out and the permutit is re-used for softening water.

(iii) *Calgon process*: Calgon is the trade name given to sodium hexametaphosphate, $Na_2(Na_4P_6O_{18})$ or $(NaPO_3)_6$. Calgon ionizes as:

$$Na_2(Na_4P_6O_{18}) \rightleftharpoons 2Na^+ + (Na_4P_6O_{18})^{2-}$$

Calgon forms soluble complexes with calcium or magnesium ions present in hard water.

$$2Ca^{2+} + (Na_4P_6O_{18})^{2-} \longrightarrow 4Na^+ + (Ca_2P_6O_{18})^{2-}$$
$$2Mg^{2+} + (Na_4P_6O_{18})^{2-} \longrightarrow 4Na^+ + (Mg_2P_6O_{18})^{2-}$$

Q. 12.10 How is natural water made suitable for drinking purposes?

Answer: Drinking water should possess the following qualities.

(i) It should be colourless and odourless.
(ii) It should be free from suspended impurities.

(iii) It should be free from germs and bacteria.

(iv) It should be free from impurities which are injurious in nature, e.g. nitrites, nitrates, ammonia, etc.

Natural water is made suitable for drinking purposes by the following methods.

(a) *Filtration*: Water is passed through beds of powdered charcoal, sand and gravel. Charcoal removes colouring matter whereas sand and gravel hold the suspended impurities, besides removing bacteria.

(b) *Sedimentation and coagulation*: Alum acts as a coagulating agent. When this is added to water, suspended particles are coagulated (i.e. they come together). Water is allowed to stand for some time after the addition of alum. The precipitate formed settles down slowly and carries with it the suspended impurities and some bacteria. The process of filtration that follows, clarifies the water further and also removes many polluting organisms.

(c) *Chlorination*: Small quantities of chlorine or bleaching powder added to water is very effective in killing harmful bacteria and making the water fit for drinking.

EXERCISES

12.1 Name the different sources of water in nature.

12.2 Give reactions of the following metals with dilute acids : (i) zinc (ii) magnesium (iii) iron (iv) aluminium.

12.3 Fill in the blanks in the following.

(i) Hydrogen is used in filling....
(ii) Hydrogen is obtained in the laboratory by the action of zinc on...
(iii) ...attacks cold water vigorously with the evolution of hydrogen gas.
(iv) ... and ... are sources of water in nature.
(v) Water is ... to litmus.
(vi) The compound used for softening water by the Calgon's process is...
(vii) Temporary hardness is caused by the presence of...of calcium and magnesium.
(viii) ...is used for the sterilization of water.
(ix) Permanent hardness of water can be removed by...
(x) Magnesium reacts with boiling water to produce...

12.4 Match the statements in column A with those in column B.

COLUMN A

(i) Hydrogen is the first element
(ii) In the laboratory hydrogen is obtained
(iii) Hydrogen is used in furnaces
(iv) Drinking water contains
(v) Sunlight kills the micro-organisms
(vi) Water which lathers readily
(vii) Water which does not lather readily
(viii) Temporary hard water on boiling becomes soft
(ix) Hydrogen is used
(x) Oxy-hydrogen flame is used

COLUMN B

(i) for welding purposes.
(ii) in the manufacture of vanaspati ghee.
(iii) by the action of zinc on dil. HCl.
(iv) because the bicarbonates of Ca and Mg are decomposed to insoluble carbonates.
(v) is known as soft water.
(vi) is known as hard water.
(vii) present in water.
(viii) dissolved air and some mineral salts.
(ix) for providing reducing atmosphere.
(x) in the periodic table.

12.5 Draw a line under the most appropriate answer.

1. Hydrogen is the first element in the periodic table. It is present in group (VII A, IA, 0).
2. Which of the following will displace hydrogen from water? (platinum, silver, potassium, gold).
3. Nickel displaces hydrogen from (cold water, boiling water, steam).
4. The cause of hardness in water is the presence of soluble salts of (Na^+ and K^+, Ca^{2+} and Mg^{2+}, NH_4^+ and Cu^{2+}).
5. Vanaspati ghee is obtained by the hydrogenation of oils. The catalyst in this process is (Cu, Ni, Al, C).
6. The chemical used for softening water by the Clark's process is [$(NaPO_3)_6$, $Ca(OH)_2$, Na_2CO_3].
7. In the permutit process Ca^{2+} and Mg^{2+} ions are exchanged with (NH_4^+, Ag^+, K^+, Na^+).
8. Which of the following is used for the sterilization of water? (chlorine, ammonia, oxygen).

12.6 Write a short note on the occurrence of hydrogen in nature.

12.7 Explain how hydrogen is used for welding purposes.

12.8 Give reactions by which hydrogen can be prepared by the action of metals on water.

12.9 How does hard water differ from soft water? How can hardness of water be removed?

12.10 Describe the behaviour of hard water towards soap.

12.11 How many types of hardness occur in hard water?

12.12 Describe the various methods used in removing (i) temporary hardness (ii) permanent hardness of water.

12.13 What are the qualities of drinking water?

12.14 What is ion exchange method? Explain.

12.15 What is meant by sterilization of water?

12.16 Why do we use alum in the purification of water?

UNIT 13

Solutions and Electrolytic Dissociations

D.13.1 Solution: A homogeneous mixture of two or more chemically non-reacting substances.

D.13.2 Solute: The dispersed phase in a solution (or the substance that is present in smaller quantity in a solution).

D.13.3 Solvent: The dispersion medium in a solution (or the substance present in larger quantity in a solution).

D.13.4 Suspension: A heterogeneous dispersion where the dispersed particles are large enough ($> 10^{-5}$ cm) to be seen by the naked eye.

D.13.5 Colloid: A heterogeneous dispersion where the dispersed particles (10^5 to 10^7 cm) can only be seen by a powerful microscope.

D.13.6 Concentration: The amount of solute dissolved in a given amount of solution or solvent.

D.13.7 Mass per cent: The ratio of the mass of one component of a solution to the total mass of the solution, multiplied by 100.

D.13.8 Mole fraction: The ratio of the number of moles of one component of a solution to the total number of moles of the solution.

D.13.9 Molarity: The number of moles of the solute present in one litre of the solution.

D.13.10 Molality: The number of moles of the solute dissolved in 1000g of the solvent.

D.13.11 Solubility: The amount of solute present in 100ml of the saturated solution.

D.13.12 Saturated solution: A solution containing the maximum amount of solute that can be dissolved in the solvent at a particular temperature.

D.13.13 Unsaturated solution: A solution containing a lower concentration of solute than a saturated solution.

D.13.14 Supersaturated solution: A solution containing a higher concentration of solute than a saturated solution.

D.13.15 Heat of solution: Heat absorbed or evolved when one mole of a substance is dissolved in water to form 1 litre of solution.

D.13.16 Conductors: Substances that allow electric current to flow through them.

D.13.17 Non-conductors: Substances that do not allow electric current to flow through them.

D.13.18 Ions: Positively and negatively charged particles formed by decomposition of an ionic compound in solution.

D.13.19 Ionization: The process of decomposition of an ionic compound in solution into its ions.

D.13.20 Electrolyte: Substances (generally electrovalent) that conduct electricity in the fused state or in solution.

D.13.21 Non-electrolytes: Covalent and neutral substances that do not conduct electricity in solution.

D.13.22 Strong electrolytes: Electrolytes capable of complete or almost complete ionization in solution.

D.13.23 Weak electrolytes: Electrolytes that are only partially ionized in solution.

D.13.24 Ionic product of water: Product of the concentration of H^+ and OH^- ions in water, expressed in moles per litre ($K_w = [H^+][OH^-]$).

D.13.25 pH: The negative logarithm to base 10 of the H^+ ion concentration in moles per litre ($pH = -\log [H^+]$).

D.13.26 Electrolysis: The phenomenon of decomposition of an electrolyte by passage of an electric current though it.

D.13.27 Anode: The positive electrode during the passage of an electric current through an electrolyte.

D.13.28 Cathode: The negative electrode during the passage of an electric current through an electrolyte.

D.13.29 Cations: Positive ions that go to the cathode during electrolysis.

D.13.30 Anions: Negative ions that go to the anode during electrolysis.

D.13.31 Electroplating: Deposition of one metal over another with the help of an electric current.

D.13.32 Electro-refining: Refining of metals such as copper tin, silver, etc. with the help of an electric current.

D.13.33 Electro-metallurgy: Extraction of metals such as sodium, calcium, etc. by electrolysing their salts in the fused state.

D.13.34 Electrotyping: The process of reproducing printing plates by electrolysis.

Q. 13.1 Explain what is meant by (i) solution (ii) solute (iii) solvent.

Answer: A *solution* is defined as a homogeneous mixture of two or more chemically non-reacting substances. A solution consists of at least two components: (i) *solvent* which forms the major part of the solution, and (ii) the *solute* which is dissolved in the solvent and is present in smaller amounts than the solvent.

In a solution of sodium chloride in water, sodium chloride is the solute and water the solvent.

The solute is also called the dispersed phase and the solvent the dispersion medium.

Q. 13.2 Enumerate the various types of solutions. Give an example of each.

Answer: The various types of solutions are listed below.

(i) Solid-liquid solution; e.g. salt in water.
(ii) Gas-liquid solution; e.g. carbon dioxide in water.
(iii) Gas-gas solution; e.g. air (containing O_2, N_2, CO_2, etc.)
(iv) Solid-solid solution. Here the atoms of one element may enter the crystals of another. Alloys (e.g. bronze) are solid-solid solutions.
(v) Liquid-liquid solution; e.g. water and ethyl alcohol.

Q. 13.3 What is a (i) solution (ii) suspension (iii) colloid.

Answer: (i) A *solution* is a dispersion of solute particles in a solvent such that the resultant mixture is homogeneous (particle size $< 10^{-7}$ cm). Example: solution of salt in water.

(ii) A *suspension* is a dispersion, where the dispersed particles are large enough (particle size $> 10^{-5}$ cm) to be seen by the naked eye. The mixture is heterogeneous and the particles settle down under gravity. Example: sand in water.

(iii) A *colloid* is a dispersion which is heterogeneous but appears to be homogeneous because the dispersed particles cannot be observed by the naked eye (particle size 10^{-5} to 10^{-7} cm). The particles are bigger than those of a solution and can be seen by a powerful microscope.

Q. 13.4 Distinguish between a solution, a suspension and a colloid.

Answer: Table 13.1 lists the major points of difference.

TABLE 13.1 DISTINCTION BETWEEN SOLUTION, SUSPENSION AND COLLOID

Property	*Solution*	*Colloid*	*Suspension*
1. Size of particles	$< 10^{-7}$ cm	10^{-5} to 10^{-7} cm	$> 10^{-5}$ cm
2. Type of mixture	Homogeneous	Heterogeneous but appears to be homogeneous	Heterogeneous
3. Appearance	Transparent	Translucent	Opaque
4. Visibility of particles	Cannot be seen even under powerful microscope	Can be seen by a powerful microscope	Visible to naked eye
5. Separation by filtration	Not possible	Cannot be separated by ordinary filtration	Can be separated by ordinary filtration

Q. 13.5 Identify the dispersed phase and the dispersion medium in each of the following colloidal systems: smoke, fog, clouds, jelly, ink, milk, butter.

Answer: See Table 13.2

TABLE 13.2

Name	*Dispersed phase*	*Dispersion medium*
Smoke	Solid	Gas
Fog	Liquid	Gas
Clouds	Liquid	Gas
Jelly	Liquid	Solid
Ink	Solid	Liquid
Milk	Liquid	Liquid
Butter	Liquid	Liquid

Q. 13.6 What are the various ways of expressing the concentration of a solution?

Answer: The concentration of a solution can be expressed in the following ways: (i) mass per cent (ii) mole fraction (iii) molarity (iv) molality.

(i) *Mass per cent*

If W_A = mass in grams of solute

W_B = mass in grams of solvent

the mass per cent of $A = \frac{W_A}{W_A + W_B} \times 100\%$

(ii) *Mole fraction*: The mole fraction X_A of a solute A in a solution is the ratio of the number of moles of A (denoted by n_A) to the total number of moles of all components. In a solution of two components

$$X_A = \frac{n_A}{n_A + n_B}$$

Mole fraction of B is

$$X_B = \frac{n_B}{n_A + n_B}$$

The sum of the mole fractions of components A and B in solution is

$$X_A + X_B = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = 1$$

(iii) *Molarity*: Molarity, denoted by M, is defined as the number of moles of the solute present per litre of the solution.

$$M = \frac{\text{number of moles of solute}}{\text{volume of solution in litres}}$$

(iv) *Molality*: Molality, denoted by m, is defined as the number of moles of the solute dissolved in 1000 g of the solvent.

$$m = \frac{\text{number of moles of solute}}{\text{number of kilograms of solvent}}$$

Q. 13.7 Define solubility of a substance and give the factors which affect it?

Answer: The solubility of a substance is its weight in grams that dissolves in 100 grams of a solvent to form a saturated solution under specified conditions of temperature and pressure. Mathematically, it is given by:

$$\text{Solubility} = \frac{\text{mass of solute}}{\text{mass of solvent}} \times 100$$

The factors that affect solubility of a substance are as follows.

(1) The solubility of a solid-liquid solution and a liquid-liquid solution generally increases with rise in temperature, while the solubility of

a gas-liquid solution increases with fall in temperature. Fig. 13.1 shows the variation of solubility of some substances with temperature.

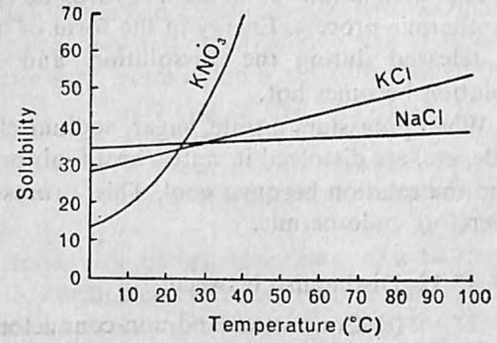


FIG. 13.1 Variation of solubility with temperature.

(2) An increase in pressure increases the solubility of a gas-liquid solution. The other types of solution are not substantially affected by change of pressure.

Q. 13.8 Explain: (i) saturated (ii) unsaturated (iii) supersaturated solution.

Answer: (i) *Saturated solution*: When a solute is added to a liquid solvent at a given temperature, it dissolves. This dissolving process gradually slows down as more and more of the solute is added. A stage reaches when this process stops and some solute remains undissolved (Fig. 13.2). There then exists a dynamic equilibrium between the solid phase and the liquid phase, the rate of dissolution being equal to the rate of crystallization. This is called a saturated solution.

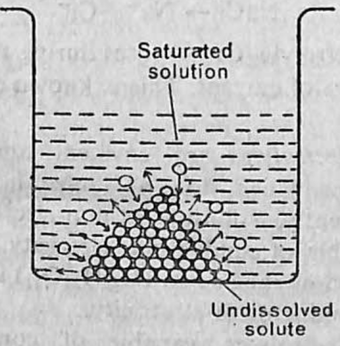


FIG. 13.2 Saturated solution.

(ii) *Unsaturated solution* : An unsaturated solution contains a lower concentration of solute than a saturated solution.

(iii) *Supersaturated solution*: A supersaturated solution is one which contains a higher concentration of solute than a saturated solution.

Q. 13.9 A small crystal of sugar is added to a sugar solution in water. How will you describe the solution if the crystal (i) remains unchanged (ii) decreases in size (iii) grows in size.

Answer: (i) Saturated solution.
(ii) Unsaturated solution.
(iii) Supersaturated solution.

Q. 13.10 Discuss the importance of water as a solvent. How do polar (ionic) and non-polar (covalent) substances dissolve in water?

Answer: Water is known as a universal solvent as it dissolves a large number of polar and non-polar substances. Water, as a solvent, is important for the life process. Plants absorb solutions of minerals in water from the soil. As a solvent water also finds immense use in almost all industries, including the pharmaceutical industry.

When a compound is introduced into water, the following forces of attraction are present:

(i) force between solute ions or molecules.
(ii) force between water molecules.
(iii) force between solute ions or molecules and water molecules.

A solute will dissolve in water only when force (iii) is large enough to overcome forces (i) and (ii).

Dissolution of polar (ionic) substance: In an ionic compound force (i) is very strong. These bonds are broken and the compound dissolves in water due to the polar character of water. In a water molecule the hydrogen atoms are positively charged and the oxygen atom is negatively charged. Due to this, an envelope of water molecules is formed around the ions (this is known as hydration of the ions). The process of hydration starts at the corners and edges of the salt crystal (Fig. 13.3). The hydrated ions acquire sufficient energy to break away and the entire solid dissolves.

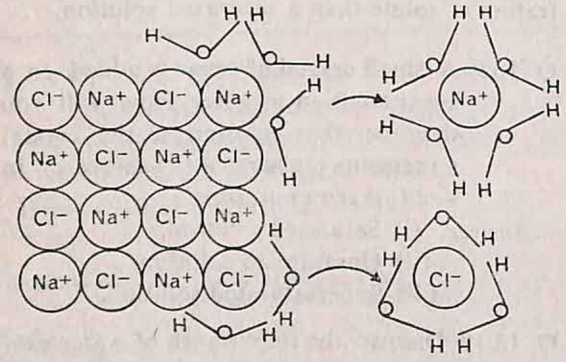


FIG. 13.3 Dissolution of an ionic compound in water.

Another factor that helps in dissolution is the high dielectric constant of water which effectively reduces the force of attraction between the solid ions.

Dissolution of non-polar (covalent) substances: Such substances (e.g. cane sugar) do not ionize in water. Here the molecules themselves are hydrated and break away to dissolve.

Q. 13.11 Define heat of solution. Explain, giving examples, why there are energy changes during dissolution of substances in water.

Answer: Heat of solution is the heat absorbed or evolved when one mole of a substance is dissolved in water to form 1 litre of solution.

When any substance is dissolved in water the following changes take place.

(i) Breaking of bonds between solute ions/molecules. This process is endothermic (energy absorbed).

(ii) Hydration of solute ions/molecules. This process is exothermic (energy released).

The dissolution will therefore be exothermic if the energy released in (ii) is greater than the energy absorbed in (i), and endothermic in the opposite case.

The dissolution of sodium hydroxide is an exothermic process. Energy in the form of heat is released during the dissolution and the solution becomes hot.

When potassium nitrate, sugar, sodium chloride, etc. are dissolved in water, heat is absorbed and the solution becomes cool. This process is therefore endothermic.

Q. 13.12 Distinguish between:

(i) Conductors and non-conductors.
(ii) Metallic conductors, electrolytes and non-electrolytes.
(iii) Strong and weak electrolytes.

Answer: (i) Substances that allow electric current to flow through them are called *conductors*. Substances that do not allow the flow of electric current through them are called *non-conductors*.

(ii) Current in metals consists of flow of electrons. The passage of current in metals does not involve any chemical change. Such conductors are known as *metallic conductors*.

Electrolytes are substances that conduct electricity in the fused state or in solution. They are generally electrovalent substances which ionize in solution. These ions then act as carriers of electricity. Example:

$$NaCl \rightarrow Na^+ + Cl^-$$

The electrolyte decomposes during the process of passage of current. This is known as *electrolysis*.

Non-electrolytes are covalent and neutral substances which do not ionize in solution. Consequently, solutions of non-electrolytes are not capable of conducting electricity. Example: a solution of cane sugar ($C_{12}H_{22}O_{11}$) in water is a non-conductor of electricity.

(iii) Electrolytes capable of complete or almost complete ionization in solution are known as *strong electrolytes*. Their electrical conductivity is high. Example: sodium chloride.

$$NaCl \rightarrow Na^+ + Cl^-$$

Electrolytes that are only partially ionized in solution and hence have low electrical conductivity are known as *weak electrolytes*. Example: acetic acid, ammonium hydroxide, etc.

$$NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

Q. 13.13 Describe an experiment to distinguish between electrolytes and non-electrolytes.

Answer: A circuit consisting of a battery, a bulb, a switch and electrodes dipping in a beaker is set up as shown in Fig. 13.4. When the beaker is filled with distilled water (Fig. 13.4a) the bulb does not glow. This indicates that distilled water is a non-conductor of electricity (i.e. a non-electrolyte). However, when the beaker is filled with sodium chloride solution the bulb glows (Fig. 13.4b). This shows that sodium chloride solution conducts electricity, that is, it is an electrolyte.

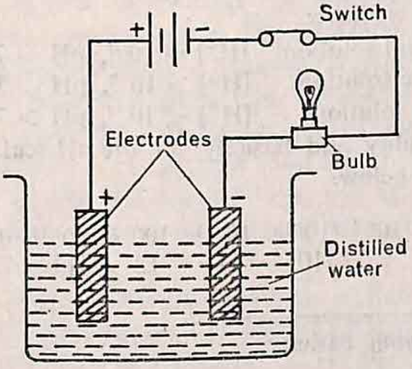


FIG. 13.4a Distilled water is a non-conductor of electricity.

This apparatus can also be used to distinguish between strong and weak electrolytes. If the experiment is performed with various electrolytes it will be seen that the bulb glows very brightly with strong electrolytes and less brightly with weak electrolytes. This is because strong electrolytes have a higher electric conductivity.

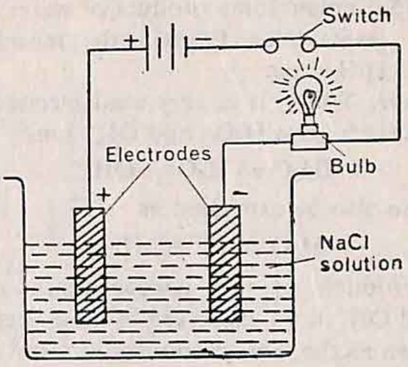


FIG. 13.4b Sodium chloride solution in water is a conductor of electricity.

Q. 13.14 Discuss the dissociation of acids, bases and salts in water.

Answer: (i) *Acids*: In aqueous solution, acids decompose to give hydronium ions (H_3O^+).

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

These H_3O^+ ions are responsible for the acidic properties of the solution.

In strong acids (HCl, H_2SO_4, HNO_3) the dissociation is almost complete.

In weak acids (acetic acid) the dissociation is partial.

$$H_2SO_4 + 2H_2O \rightarrow 2H_3O^+ + SO_4^{2-}$$
$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$
$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

The number of hydronium ions produced per molecule of an acid is known as its *basicity*. Thus HCl and HNO_3 are monobasic. H_2SO_4 is dibasic.

(ii) *Bases*: Bases dissociate in water to form hydroxyl (OH^-) ions and cations. Strong bases (e.g. NaOH, KOH) decompose almost completely while weak bases (e.g. NH_4OH) decompose partially.

$$NaOH \rightarrow Na^+ + OH^-$$
$$NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

(iii) *Salts*: A salt is a substance formed by replacing the hydrogen ion (H^+) of an acid by a metal ion. Example

$$HCl + NaOH \rightarrow \underset{\text{salt}}{NaCl} + H_2O$$

Q. 13.15 Explain ionic product of water. What is its value? Explain the meaning of pH scale.

Answer: Water is a very weak electrolyte. It dissociates to give H_3O^+ and OH^- ions.

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

This can also be expressed as

$$H_2O \rightleftharpoons H^+ + OH^-$$

The product of the concentration of the H^+ and OH^- ions, expressed in moles per litre, is known as the *ionic product of water*, K_w

$$K_w = [H^+][OH^-]$$

The square brackets indicate concentration of the ions.

The concentration of each of the two ions at 25°C is known to be 10^{-7} mole per litre. Therefore

$$K_w = 10^{-7} \times 10^{-7} = 10^{-14}$$

pH scale: In a neutral solution

$$[H^+] = [OH^-] = 10^{-7}$$

In an acidic solution $[H^+] > [OH^-]$

that is
$$[H^+] > 10^{-7}$$
$$[OH^-] < 10^{-7}$$

In a basic solution
$$[H^+] < [OH^-]$$

that is
$$[H^+] < 10^{-7}$$
$$[OH^-] > 10^{-7}$$

Thus the acidity or basicity of a solution can be described by specifying the concentration of H^+ ions. For this purpose the term pH was introduced by Sorenson in 1909. It is defined as the negative logarithm to base 10 of the hydrogen ion (H^+) concentration in moles per litre. Thus

$$pH = -\log [H^+]$$
$$= \log \frac{1}{[H^+]}$$

Thus we have:

Neutral solution: $[H^+] = 10^{-7}$, pH $= 7.0$

Acidic solution: $[H^+] > 10^{-7}$, pH < 7.0

Basic solution: $[H^+] < 10^{-7}$, pH > 7.0

Acidity and basicity on the pH scale are as given below.

$[H^+]$	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
pH	1	2	3	4	5	6	7	8	9	10	11	12	13	14

← increasing acidity | increasing basicity →

neutral

Q. 13.16 Give a brief account of the process of electrolysis.

Answer: Electrolysis is the phenomenon of decomposition of an electrolyte by passage of an electric current through it. The current is carried by ions present in the solution. During electrolysis, two metal rods, called electrodes, are dipped in the solution of electrolyte and joined to a battery (Fig. 13.5). The positive electrode or *anode* is the one connected to the positive pole of the battery and the negative electrode or *cathode* is connected to the negative pole of the battery. In the solution, the direction of flow of current is from anode to cathode. During electrolysis, positive ions or *cations* go

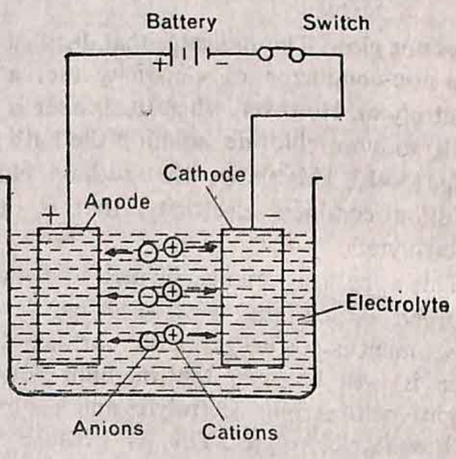


Fig. 13.5 Electrolysis.

to the cathode while negative ions or *anions* are discharged at the anode. For example, in the electrolysis of potassium chloride solution, the following reactions take place.

$$KCl \rightarrow \underset{\text{cation}}{K^+} + \underset{\text{anion}}{Cl^-}$$

At cathode $K^+ + e^- \rightarrow K$ (liberated at the cathode)

At anode $Cl^- \rightarrow Cl + e^-$

$$\downarrow 2Cl$$

Cl_2 (liberated at the anode)

Q. 13.17 What are the main applications of electrolysis?

Answer: Following are some of the major applications of electrolysis.

(a) *Electroplating*: This process consists of depositing one metal over the other with the help of an electric current. The deposited metal is generally superior and possesses certain characteristic properties. Metals like silver and gold are deposited on metallic copper to make it more attractive. Chromium and nickel are deposited on iron to protect it from rusting. Thus electroplating is done for decoration as well as for protection.

The article to be electroplated is first well cleaned with a solution of alkali to remove any grease and then with acid to remove any oxide on the surface. It is then made the cathode in a solution of a suitable salt of the metal to be deposited. A thin sheet of pure metal is made the anode. With the passage of electric current, the anode goes on dissolving and metal ions from the solution get deposited on the article. Thus in silver plating, the anode consists of pure silver and the electrolyte is a solution of sodium argento-cyanide, $NaAg(CN)_2$ (Fig. 13.6). The following reactions take place.

$$AgCN \rightarrow Ag^+ + CN^-$$

At cathode $Ag^+ + e^- \rightarrow Ag$

At anode $\underset{\text{from anode}}{Ag} + CN^- \rightarrow AgCN + e^-$

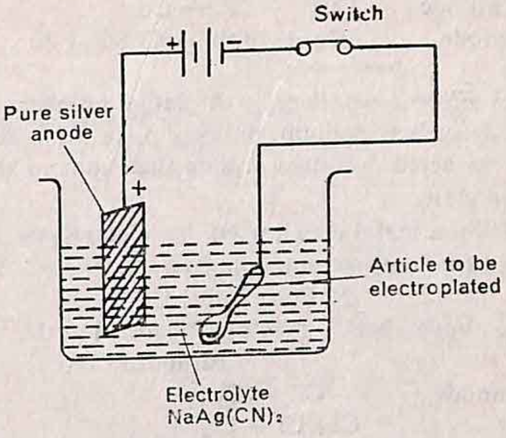


FIG. 13.6 Electroplating of silver.

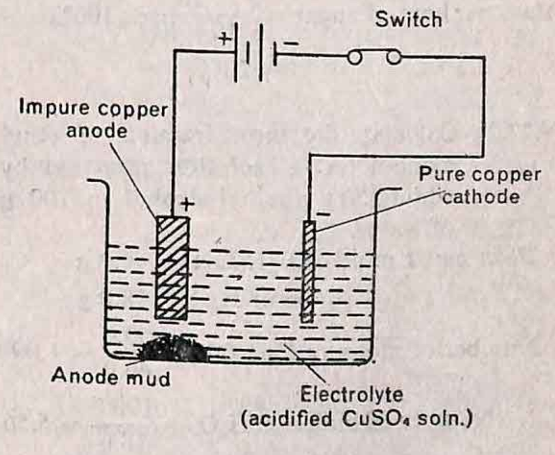


FIG. 13.7 Electro-refining of copper.

(b) *Electro-refining of metals*: Metals like copper, tin, aluminium and silver are refined electrolytically. The impure metal is made the anode and a thin sheet of pure metal is made the cathode. A suitable salt of the metal is taken as an electrolyte. On passing electricity the anode goes on dissolving and pure metal gets deposited on the cathode. Fig. 13.7 shows electro-refining of copper. The impurities either go into the solution or are deposited at the bottom of the anode as anode mud. With the electrolyte being acidified copper sulphate the reactions are as follows.

$$CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$$

At cathode $Cu^{2+} + 2e^- \rightarrow Cu$

At anode $\underset{\text{from anode}}{Cu} + SO_4^{2-} \rightarrow CuSO_4 + 2e^-$

(c) *Electro-metallurgy*: A large number of metals such as sodium, potassium, calcium, etc. are extracted by electrolysing their salts in the fused state.

Sodium metal is extracted by electrolysis of fused (molten) sodium chloride.

$$NaCl \rightarrow Na^+ + Cl^-$$

At cathode $Na^+ + e^- \rightarrow Na$ (liberated at the cathode)

At anode $Cl^- \rightarrow Cl + e^-$

$$Cl + Cl \rightarrow Cl_2$$

(d) *Electrotyping*: Electrotyping is the process of reproducing the form of an object, for example a type page, for printing.

A wax cast of the object is first made. Finely divided graphite is then sprinkled over this to make it conducting. The cast is then made the cathode in an electrolytic bath of copper sulphate. A copper plate is made the anode. On passing an electric current the copper metal deposits over the cathode. When the deposited film is sufficiently thick the cast is taken out and the wax removed. The copper impression left is reinforced by filling its back side with molten type metal.

The cast thus obtained can be used for large scale printing.

NUMERICALS

N.13.1 Calculate the mass per cent of sugar in a solution containing 40 g of water and 10 g of sugar.

Solution: $W_{\text{sugar}} = 10\text{ g}, W_{\text{water}} = 40\text{ g}$

$$\text{Mass per cent of sugar} = \frac{10}{10+40} \times 100\% = 20\%$$

N.13.2 Calculate the mole fraction of ethyl alcohol in a solution prepared by adding 50 g of ethyl alcohol to 100 g of water.

Solution: 1 mole of $C_2H_5OH = 46.0$ g

1 mole of $H_2O = 18.0$ g

$$\text{Number of moles of } C_2H_5OH = \frac{50.0}{46.0} = 1.09$$

$$\text{Number of moles of } H_2O = \frac{100.0}{18.0} = 5.56$$

$$X_{C_2H_5OH} = \frac{1.09}{1.09+5.56} = 0.164$$

N.13.3 18.0 g of glucose is present in 100 ml of solution. Calculate the molarity of the solution. (Mol.wt. of glucose = 180)

Solution

1 mole of glucose = 180 g

Wt. of glucose = 18 g

$$\therefore \text{Number of moles of glucose} = \frac{18}{180} = 0.1$$

Volume of solution = 100 ml = 0.1 litre

$$\text{Hence, molarity } M = \frac{0.1}{0.1} = 1$$

N.13.4 Calculate the molality of a solution prepared by dissolving 16 g of barium chloride in 192 g of water.

Solution: 1 mole of $BaCl_2 = 208.2$ g

Wt. of $BaCl_2 = 16$ g

$$\therefore \text{Number of moles of } BaCl_2 = \frac{16}{208.2} = 0.0769$$

0.0769 moles of $BaCl_2$ are dissolved in 192 g of water. Therefore, molality

$$m = \frac{0.0769}{192} \times 1000 = 0.40$$

N.13.5 Calculate the pH of solutions with following $[H^+]$: (i) 10^{-6} (ii) 10^{-2} (iii) 10^{-8} (iv) 10^{-12}.

Solution: (i) $[H^+] = 10^{-6}M$

By definition,

$$pH = -\log [H^+] = -\log 10^{-6} = -(-6) = 6$$

(ii) $[H^+] = 10^{-2}M$

$$pH = -\log 10^{-2} = -(-2) = 2$$

(iii) $[H^+] = 10^{-8}M$

$$pH = -\log 10^{-8} = -(-8) = 8$$

(iv) $[H^+] = 10^{-12}$

$$pH = -\log 10^{-12} = -(-12) = 12$$

N.13.6 Calculate the $[H^+]$ in solutions of the following pH: (i) 7 (ii) 9 (iii) 3 (iv) 5.

Solution: (i) pH = 7

By definition, $pH = -\log [H^+] = \log \dfrac{1}{[H^+]}$

or $\log \dfrac{1}{[H+]} = 7$

Taking antilogs of both sides

$$\frac{1}{[H+]} = 10^7$$

or $[H^+] = \dfrac{1}{10^7} = 10^{-7}M$

(ii) pH = 9

$$\log \frac{1}{[H^+]} = 9$$

Taking antilogs of both sides

$$\frac{1}{[H^+]} = 10^9$$

or $[H^+] = \dfrac{1}{10^9} = 10^{-9}M$

(iii) pH = 3

$$\log \frac{1}{[H^+]} = 3$$

Taking antilogs of both sides

$$\frac{1}{[H^+]} = 10^3$$

or $[H^+] = \dfrac{1}{10^3} = 10^{-3}M$

(iv) pH = 5

$$\log \frac{1}{[H^+]} = 5$$

Taking antilogs of both sides

$$\frac{1}{[H^+]} = 10^5$$

or $[H^+] = \dfrac{1}{10^5} = 10^{-5}M$

N.13.7 Four solutions *A*, *B*, *C* and *D* have pH values 2.5, 5.4, 8.3 and 10.5 respectively.

(a) Which of these is most basic and which is most acidic?

(b) Arrange them in order of decreasing $[H^+]$.

Solution: (a) Solution *D*, pH = 10.5, is the most basic.

Solution *A*, pH = 2.5, is the most acidic.

(b) $[H^+]_A > [H^+]_B > [H^+]_C > [H^+]_D$

EXERCISES

13.1 Indicate whether the following are solutions, suspensions or colloidal solutions.

(a) Sand (b) Blood (c) Gum (d) Carbon in air (e) Common salt dissolved in water (f) Soda water (g) Smoke (h) Paint (i) Alloys.

13.2 Categorise the following into electrolytes and non-electrolytes.

(a) Ammonium chloride (aq) (b) Carbon tetrachloride (c) Sugar solution (aq) (d) Common salt solution in water (e) Copper sulphate (aq) (f) Ethyl alcohol (aq).

13.3 The following electrolytes get ionized in aqueous solutions. Name the respective anions and cations indicating the charge on them.

(a) $AgNO_3$ (b) K_2SO_4 (c) $Al(OH)_3$ (d) $BaCl_2$ (e) $CuSO_4$.

13.4 What is the difference between electrolytes and non-electrolytes?

13.5 Two solutions *A* and *B* have pH values of 3.0 and 9.5 respectively. Which of these will turn blue litmus red and which will turn phenolphthalein solution from colourless to pink?

13.6 Fill in the blanks.

(i) A true solution is a......mixture of two or more components.

(ii) Molality of a solute in any solution is equal to the number of......of solute per......of the solvent.

(iii) ......electrolytes are completely dissociated in aqueous solution.

(iv) The pH value of an alkaline solution is...... 7.

(v) A positively charged ion is called.......

(vi) Non-electrolytes give ...... conducting solutions.

13.7 Match the statements in column A with those in column B.

COLUMN A

1. Solution is a homogeneous mixture
2. The substance that is present in smaller quantity
3. The substance that is present in larger quantity
4 The concentration of a solution is expressed
5. Electrolysis is the phenomenon of decomposition of an
6. pH is equal to the negative of logarithm
7. A solution is acidic
8. A solution is basic
9. The substances which permit electric current
10. The particle size of the dispersed phase in a colloid is

COLUMN B

1. in terms of mass per cent, mole fraction, molarity, molality.
2. in the solution is called a solvent.
3. of hydrogen ion concentration.
4. of two or more substances.
5. in the solution is called a solute.
6. to flow through are called conductors.
7. 10^{-5} to 10^{-7} cm.
8. if its pH is greater than 7.
9. if its pH is less than 7.
10. electrolyte by passage of an electric current through it.

13.8 Draw a line under the most appropriate answer.

1. A mixture of sawdust in water is an example of (colloid, solution, suspension.)
2. The particle size in a solution is ($> 10^{-5}$ cm, $< 10^{-7}$ cm, 10^{-5} to 10^{-7} cm)
3. The number of moles of the solution present per litre of the solution is called its (molarity, molality, mole fraction)
4. The mole fraction of a component in a solution is always (>1, 1, <1)
5. If in a solution, there exists a dynamic equilibrium between the solid phase and the liquid phase, it is called a (unsaturated solution, saturated solution, supersaturated solution).

13.9 Explain the terms: (i) solute (ii) solvent (iii) solution (iv) mass per cent (v) mole fraction (vi) molarity (vii) molality.

13.10 What are the main characteristics of a solution? How many types of solutions are possible on the basis of the three different physical states of matter.

13.11 What is the difference between solutions and colloids?

13.12 Describe a suitable experiment to demonstrate the electrical conductivity of a solution.

13.13 What is a saturated solution? Give an experiment to verify whether a solution is saturated, unsaturated or supersaturated.

13.14 Two drinks *P* and *Q* gave acidic and alkaline reactions respectively. One has a pH of 9 and the other of 3. Which drink is acidic and which is basic?

13.15 What is the difference between weak and strong electrolytes?

13.16 Explain the following terms.
(a) Cathode (b) Anode (c) Conductor (d) Non-conductor (e) Cation (f) Anion.

13.17 What is electrolysis? Describe some important applications of electrolysis in industries.

UNSOLVED NUMERICALS

13.1 What mass of sodium chloride would be required to make 500 g of a 5% solution of that salt? (*Ans.* 25 g)

13.2 6.84 g of sucrose is dissolved in 200 ml of the solution. Calculate its molarity (M.wt. of sucrose = 342). (*Ans.* 0.1)

13.3 What are the weights of the solutes in the following solutions of given molarities.

(a) 500 ml of M/5 oxalic acid solution.

(b) 1 litre of M/20 sodium hydroxide.

(c) 2 litres of M/2 sulphuric acid solution.

(d) 250 ml of decimolar glucose solution.

13.4 In how much weight of water would 292.5 g of sodium chloride be dissolved to obtain a 0.25 molal solution? (M.wt. of NaCl = 58.5) (*Ans.* 20 kg)

13.5 The average concentration of sodium ions in human blood serum is about 3.4 g/l. What is the

molarity of Na^+? (At wt. of Na = 23)
(*Ans.* 0.15 molar)

13.6 The volume of two solutions, one having 120 g of urea and the other an equal quantity of sodium hydroxide, are 1 litre each. Calculate their molarities. (*Ans.* urea = 2M, NaOH = 3M)

13.7 What is the amount of sulphuric acid present in 5 litres of M/2 H_2SO_4? (*Ans.* 245 g)

13.8 Calculate the pH of solutions with the following $[H^+]$: (i) 10^{-7} (ii) 10^{-9} (iii) 10^{-5} (iv) 10^{-10}.

13.9 Calculate the $[H^+]$ in solutions of the following pH: (i) 12 (ii) 6 (iii) 4 (iv) 8.

UNIT 14

Types of Chemical Changes and Rates of Reactions

D.14.1 Physical change: A change in which no new substance is formed.

D.14 2 Chemical change: A change in which new substances with new properties are formed.

D.14.3 Combination reaction: A reaction in which a new substance is formed as a result of direct combination of its constituents.

D.14.4 Decomposition reaction: Breaking of a compound into simpler substances.

D.14.5 Substitution reaction: A reaction in which an atom or a group of atoms in a compound are replaced by another atom or group of atoms.

D.14.6 Reversible reaction: A reaction which can proceed in both directions.

D.14.7 Irreversible reaction: A reaction in which the reactant or reactants cannot be obtained from the products under any conditions.

D.14.8 Homogeneous reaction: A reaction in which the reactants and products are in the same phase.

D.14.9 Heterogeneous reaction: A reaction in which the reactants and products are in different phases.

D.14.10 Oxidation: A process in which an atom or an ion loses electrons.

D.14.11 Reduction: A process in which an atom or an ion gains electrons.

D.14.12 Oxidizing agent: A substance which can oxidize other substances by accepting electrons.

D.14.13 Reducing agent: A substance which can reduce other substances by supplying electrons.

D.14.14 Redox reaction: A reaction in which reduction and oxidation take place simultaneously.

D.14.15 Oxidation number: A number used to indicate oxidation and reduction.

D.14.16 Exothermic reaction: A reaction which takes place with the evolution of heat.

D.14.17 Endothermic reaction: A reaction which takes place with the absorption of heat.

D.14.18 Chemical kinetics: The study of the rate of chemical reactions.

D.14.19 Rate of reaction: Change per unit time of the concentration (number of moles per unit volume) of one of the reactants or products in the reaction.

D.14.20 Law of mass action: The rate of a chemical reaction is proportional to the product of the effective concentration of the reacting substances.

D.14.21 Chemical equilibrium: A state when the rates of the forward and backward reactions are the same.

D.14.22 Equilibrium constant: In the reaction $A+B \rightleftharpoons C+D$ the equilibrum constant K is given by $K = [C][D]/[A][B]$.

D.14.23 Catalyst: A substance which alters the speed of a chemical reaction without itself undergoing any chemical change.

D.14.24 Le Chatelier's principle: If a system in chemical equilibrium is altered in any way, the system will respond in such a way as to minimise the effect of the change.

Q. 14.1 (a) Explain the terms physical change and chemical change.

(b) Indicate whether the following are physical changes or chemical changes.

- (i) Melting of ice.
- (ii) Burning of candle.
- (iii) Magnetisation of iron.
- (iv) Electrolysis of water.
- (v) Formation of frost on windows.
- (vi) Burning of magnesium ribbon.
- (vii) Crystallisation of salt from water solution.
- (viii) Conversion of electricity to light.

Answer: (a) *Physical change*: Water can exist as gas, solid or liquid. In all these states it maintains its unique composition. An iron wire on heating glows. A salt on dissolving in water forms a solution. All these changes are temporary and can be easily reversed and the substance restored to its original form. Thus, a change in which no new substance has been made is called a physical change.

Chemical change: Changes such as electrolysis of water, burning of paper, and souring of milk are such that in all these processes new substances are formed. These changes cannot be reversed. Thus changes in which new substances with new properties are formed are called chemical changes.

Physical change	*Chemical change*
Melting of ice.	Burning of candle.
Magnetisation of iron.	Electrolysis of water.
Formation of frost on windows.	Burning of magnesium ribbon.
Crystallisation of salt from water solution.	Souring of milk.

Q. 14.2 Define giving examples the following chemical reactions : (a) Combination (b) Decomposition (c) Substitution (d) Double decomposition.

Answer: (a) *Combination reactions* : In these reactions a new substance is formed as a result of direct combination of its constituents, e.g.

(i) $2Mg+O_2 \longrightarrow 2MgO$

(ii) $H_2+Cl_2 \longrightarrow 2HCl$

(iii) $N_2+3H_2 \longrightarrow 2NH_3$

(b) *Decomposition reactions*: Decomposition reactions are those in which a substance breaks up into simpler substances which are chemically different from it, e.g.

(i) $CaCO_3 \xrightarrow{\text{heat}} CaO+CO_2$

(ii) $2H_2O \xrightarrow{\text{electrolysis}} 2H_2+O_2$

(iii) $2Pb(NO_3)_2 \xrightarrow{\text{heat}} 2PbO+4NO_2+O_2$

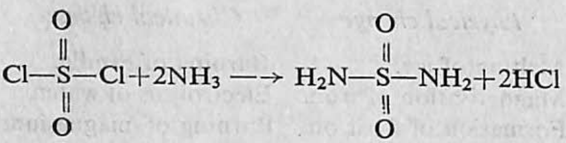
(c) *Substitution reactions*: Substitution reactions are those in which an atom or group of atoms is replaced by another atom or group of atoms, e.g.

(i) $Fe+CuSO_4 \longrightarrow FeSO_4+Cu$

(ii) The reactions between methane and chlorine involves successive replacement of four hydrogen atoms by chlorine:

$$CH_4+Cl_2 \longrightarrow CH_3Cl+HCl$$
$$CH_3Cl+Cl_2 \longrightarrow CH_2Cl_2+HCl$$
$$CH_2Cl_2+Cl_2 \longrightarrow CHCl_3+HCl$$
$$CHCl_3+Cl_2 \longrightarrow CCl_4+HCl$$

(iii) Substitution reactions are very common in organic chemistry. For example,



$$Cl-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-Cl+2NH_3 \longrightarrow H_2N-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-NH_2+2HCl$$

(d) *Double decomposition reactions*: Double decomposition reactions are those in which the reactants mutually exchange their ions, e.g.

(i) $AgNO_3+NaCl \longrightarrow AgCl+NaNO_3$
(ii) $BaCl_2+H_2SO_4 \longrightarrow BaSO_4+2HCl$
(iii) $CuSO_4+2NaOH \longrightarrow Cu(OH)_2+Na_2SO_4$

Q. 14.3 What are reversible and irreversible reactions? Illustrate with appropriate examples.

Answer

Reversible reactions: Reactions which can proceed in both directions are called reversible reactions. For example, when H_2 and I_2 are heated at 793K in a closed container, both H_2 and I_2 partially combine to form HI. If HI is introduced in the same closed container at the same temperature, HI partially decomposes to form H_2 and I_2.

$$2HI \rightleftharpoons H_2+I_2$$

Other examples are :

$$2SO_2+O_2 \rightleftharpoons 2SO_3$$
$$N_2+3H_2 \rightleftharpoons 2NH_3$$
$$PCl_5 \rightleftharpoons PCl_3+Cl_2$$
$$3Fe+4H_2O \rightleftharpoons Fe_3O_4+4H_2$$

Irreversible reactions: Reactions where the reactant or reactants cannot be obtained from the products under any conditions are known as irreversible reactions. Examples are as follows:

$$NaCl+AgNO_3 \longrightarrow AgCl+NaNO_3$$
$$2Mg+O_2 \longrightarrow 2MgO$$

Q. 14.4 What are homogeneous and heterogeneous reactions? Illustrate with suitable examples.

Answer: *Homogeneous reactions* are those in which the reactants and products are in the same phase. For example,

$$2SO_2(g)+O_2(g) \longrightarrow 2SO_3(g)$$
$$NaOH(aq)+HCl(aq) \longrightarrow NaCl(aq)+H_2O$$
$$H_2(g)+Cl_2(g) \longrightarrow 2HCl(g)$$
$$N_2(g)+3H_2(g) \longrightarrow 2NH_3(g)$$

Heterogeneous reactions are those in which the reactants and products are in different phases. For example,

$$2Mg(s)+O_2(g) \longrightarrow 2MgO(s)$$
$$CaCO_3(s)+2HCl(aq) \longrightarrow CaCl_2(aq)+H_2O+CO_2(g)$$
$$Zn(s)+2HCl(aq) \longrightarrow ZnCl_2(aq)+H_2(g)$$
$$3Fe(s)+4H_2O(g) \longrightarrow Fe_3O_4(s)+4H_2(g)$$

Q. 14.5 (i) Explain oxidation and reduction, giving their electronic concepts. Give two examples of each.
(ii) Explain what is meant by a redox reaction. Give two examples.
(iii) What are oxidizing and reducing agents? List some common examples.

Answer: (i) *Oxidation* is a process involving addition of oxygen or any other electronegative radical, or any process involving removal of hydrogen or any other electropositive radical.

In the electronic concept this is generalised and oxidation is defined as a process in which an atom or an ion loses electrons.

(a) In the reaction

$$2FeCl_2+Cl_2 \longrightarrow 2FeCl_3$$

iron (II) ions are oxidized to iron (III) ions by losing electrons.

$$Fe^{2+}-e^- \longrightarrow Fe^{3+}$$

(b) In the reaction

$$2Mg+O_2 \longrightarrow 2MgO$$

magnesium is oxidized

$$Mg-2e^- \longrightarrow Mg^{2+}$$

Reduction is a process involving removal of oxygen or any other electronegative radical, or any process involving addition of hydrogen or any other electropositive radical.

In the electronic concept, reduction is defined as a process in which an atom or an ion gains electrons.

(a) In the reaction

$$H_2S + Cu \longrightarrow CuS + H_2$$

hydrogen is reduced as the hydrogen atom gains an electron during the reaction.

(b) In the reaction

$$2FeCl_3 + H_2 \longrightarrow 2FeCl_2 + 2HCl$$

iron (III) ions are reduced to iron (II) ions.

$$Fe^{3+} + e^- \longrightarrow Fe^{2+}$$

(ii) In a reaction if one substance gains electrons (reduction), another substance must lose electrons (oxidation). Thus the process of oxidation and reduction always occur simultaneously. Such reactions are known as redox (reduction+oxidation) reactions.

(a) In the reaction

$$CuO + H_2 \longrightarrow Cu + H_2O$$

the electronic transfers are as follows.

$$Cu^{2+} + 2e^- \longrightarrow Cu \quad \text{Reduction}$$
$$H_2 + O^{2-} \longrightarrow H_2O + 2e^- \quad \text{Oxidation}$$

(b) In the reaction

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$$

we have

$$Cu^{2+} + 2e^- \longrightarrow Cu \quad \text{Reduction}$$
$$Zn - 2e^- \longrightarrow Zn^{2+} \quad \text{Oxidation}$$

(iii) Substances which can oxidise other substances by accepting electrons are called oxidizing agents. Substance which can reduce other substances by supplying electrons are called reducing agents.

Common oxidizing agents are oxygen, chlorine, sulphuric acid, nitric acid, ozone (O_3), potassium permanganate ($KMnO_4$), potassium dichromate ($K_2Cr_2O_7$), hydrogen peroxide (H_2O_2), etc.

Common reducing agents are hydrogen, carbon, sulphur dioxide, hydrogen sulphide, hydrogen iodide, etc.

Q. 14.6 (i) What is oxidation number? What are the rules for assigning oxidation numbers?

(ii) Assign oxidation numbers to (a) Mn in $KMnO_4$ (b) S in SO_4^{2-}.

Answer: (i) Oxidation and reduction can be indicated by a number known as oxidation number. The rules for assigning these numbers are as follows.

(1) The oxidation number of an element in the free state (e.g. Cl in Cl_2) is 0.

(2) The sum of the oxidation numbers of the elements in any neutral compound is 0.

(3) The sum of the oxidation numbers of the elements of an ion is the same as the number of charges on the ion, and has the same sign.

(4) The oxidation number of the elements of Group IA is taken as +1, and of oxygen as −2.

(ii) (a) Let the oxidation number of Mn atom in $KMnO_4$ be x.

Oxidation number of K $= +1$

of O $= -2$

$\therefore \quad 1 + x - 8 = 0$

or $\quad x = +7$

(b) Let the oxidation number of S in SO_4^{2-} be x.

Oxidation number of O $= -2$

$\therefore \quad x - 8 = -2$

or $\quad x = +6$

Q. 14.7 Indicate, for each of the following :

$$2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$$
$$SnO_2 + 2CO \longrightarrow Sn + 2CO_2$$

(i) The element that is oxidised.

(ii) The element that is reduced.

(iii) The substance that acts as an oxidizing agent.

(iv) The substance that acts as a reducing agent.

Answer: (a) In

$$2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$$

Iron is reduced $Fe^{3+} + e^- \longrightarrow Fe^{2+}$

Sulphur is oxidised $S^{2-} - 2e^- \longrightarrow S$

$FeCl_3$ acts as an oxidising agent.

H_2S acts as a reducing agent.

(b) In

$$SnO_2 + 2CO \longrightarrow Sn + 2CO_2$$

Sn is reduced $Sn^{4+} + 4e^- \longrightarrow Sn$

Carbon is oxidised $C^{2+} - 2e^- \longrightarrow C^{4+}$

SnO_2 acts as an oxidising agent.

CO acts as a reducing agent.

Q. 14.8 What are exothermic and endothermic reactions? Illustrate with appropriate examples.

Answer

Exothermic reaction: A reaction which takes place with the evolution of heat is called an exothermic reaction. For example, magnesium and oxygen combine to form magnesium oxide.

$$2Mg + O_2 \longrightarrow 2MgO + heat$$

Other examples are :

$$N_2 + 3H_2 \longrightarrow 2NH_3 + heat$$
$$Sn + Cl_2 \longrightarrow SnCl_2 + heat$$
$$H_2 + Cl_2 \longrightarrow 2HCl + heat$$

Endothermic reaction: A reaction which takes place with the absorption of heat is called an endothermic reaction. For example, nitrogen and oxygen combine to form nitric oxide.

$$N_2 + O_2 + heat \longrightarrow 2NO$$

Other examples are :

$$2HgO + heat \longrightarrow 2Hg + O_2$$
$$2H_2O + heat \longrightarrow 2H_2 + O_2$$
$$6CO_2 + 6H_2O + heat \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6} + 6O_2$$

Q. 14.9 What is chemical kinetics and the rate of a reaction?

Answer: An iron nail rusts slowly in air. White phosphorus burns at a fast rate when exposed to air. Also, paper burns at a fast rate once it is ignited. These reactions take place at different rates. *Chemical kinetics* deals with the study of the speed or rate of chemical reactions.

The *rate of a reaction* is measured by the amount of reactants converted to products in unit time. It is defined as the change per unit time of the concentration (number of moles per unit volume) of one of the reactants or products in the reaction. Consider the reaction

$$CO(g) + NO_2(g) \longrightarrow CO_2(g) + NO(g)$$

The rate of the reaction would be the change in concentration of CO, NO_2, CO_2 or NO, which occurs in unit time. The rate of a given chemical reaction is dependent on several factors.

Q. 14.10 What are the factors which affect the rate of a chemical reaction?

Answer: (i) *The nature of the reactants*: The rates of reactions are affected considerably by the nature of the reactants. For example, though the following reactions are very similar in nature, the first reaction proceeds at a much faster rate than the second, under similar conditions.

$$2NO + O_2 \longrightarrow 2NO_2 \qquad \text{fast}$$
$$2CO + O_2 \longrightarrow 2CO_2 \qquad \text{slow}$$

Sodium and potassium burn when exposed to air. On the other hand, platinum and gold are not attacked at all.

These examples show very clearly that reaction rates depend on the properties of the reactants.

(ii) *Effect of concentration*: Chemical reactions depend on the collisions between the reacting molecules. When the concentration of a reactant increases, the number of molecules or ions in a given volume increases. Thus the number of collisions in one second increases. Hence the reaction rate increases.

(iii) *Effect of temperature*: The rates of chemical reactions are considerably influenced by temperature. An increase in temperature results in an increase in the energy of the molecules or ions of the reactants. This leads to increase in the number of collisions and hence the reaction rate increases.

(iv) *Action of catalysts*: A catalyst is a substance that changes the rate of a reaction without itself undergoing any chemical change. Many slow chemical reactions can be made to take place more rapidly in the presence of a catalyst. For example, the reaction

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

is speeded up by the addition of a catalyst, manganese dioxide.

(v) *State of the reactants*: When one of the reactants in a reaction is a solid, the reaction takes place at the surface only. A greater surface area leads to more collisions between reacting molecules and hence the reaction is faster. The surface area of a solid reactant increases as the particle size decreases. Therefore, the smaller the size of the particles, the faster is the reaction. For example, powdered coal burns more readily in air than a large lump of coal.

Q. 14.11 State and explain the law of mass action.

Answer: The law of mass action was first suggested by Norwegian chemists Guldberg and Waage in 1864. It states that the rate at which a substance reacts is proportional to its active mass and the rate of a chemical reaction is proportional to the product of the active masses of the reactants. (Active mass is the molar concentration of the reactant.) Consider the reaction

$$A \longrightarrow \text{Product}$$

According to the law of mass action

The rate of the reaction $R \propto [A]$

For the reaction

$$A+B \longrightarrow C+D$$

$$R \propto [A]\times[B]$$

Q. 14.12 What is chemical equilibrium? Derive equilibrium constant.

Answer: When a chemical reaction takes place in a closed container at a given temperature, it proceeds to a certain point and no further. At this point the amounts of each reactant and product remain constant with time. The system is then said to be in a state of *chemical equilibrium*. At this point the rates of the forward and backward reactions are the same.

At equilibrium, the rate of forward reaction r_f is equal to the rate of backward reaction r_b, i.e.

$$r_f = r_b$$

Consider a reversible reaction

$$A+B \rightleftharpoons C+D$$

Applying the law of mass action

$$r_f \propto [A]\times[B] = K_f\,[A][B] \qquad \text{(i)}$$

$$r_b \propto [C]\times[D] = K_b\,[C][D] \qquad \text{(ii)}$$

where K_f and K_b are the rate constants of the forward and backward reactions respectively.

At equilibrium,

$$r_f = r_b$$

hence $$K_f\,[A][B] = K_b\,[C][D]$$

or $$\frac{K_f}{K_b} = \frac{[C][D]}{[A][B]} = K \qquad \text{(iii)}$$

K, which is equal to the ratio of the two rate constants, is called the *equilibrium constant*. The equation (iii) is called the *law of chemical equilibrium*.

In general, for the equation

$$aA+bB \rightleftharpoons cC+dD$$

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Q. 14.13 Formulate expressions for the equilibrium constant, K, for each of the following :

(i) $COCl_2 \rightleftharpoons CO+Cl_2$

(ii) $CO+2H_2 \rightleftharpoons CH_3OH$

(iii) $N_2O_4 \rightleftharpoons 2NO_2$

(iv) $N_2+3H_2 \rightleftharpoons 2NH_3$

(v) $H_2+Cl_2 \rightleftharpoons 2HCl$

(vi) $PCl_5 \rightleftharpoons PCl_3+Cl_2$

Answer: (i) $K = \dfrac{[CO][Cl_2]}{[COCl_2]}$

(ii) $K = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

(iii) $K = \dfrac{[NO_2]^2}{[N_2O_4]}$

(iv) $K = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$ (15)

(v) $K = \dfrac{[HCl]^2}{[H_2][Cl_2]}$

(vi) $K = \dfrac{[PCl_3][Cl_2]}{[PCl_5]}$

Q. 14.14 State and explain, with an example, Le Chatelier's principle.

Answer: Le Chatelier's principle states that if a system in chemical equilibrium is altered in any way, the system will respond in such a way as to minimise the effect of the change.

Le Chatelier's principle can be used to explain the effects of changes in temperature, pressure and concentration of a reaction.

Consider the effect of these factors on the following reaction (formation of ammonia by the Haber's process), once equilibrium has been attained.

$$N_2+3H_2 \rightleftharpoons 2NH_3+\text{heat}$$

(i) *Effect of temperature*: If the temperature of the system is lowered, the system will shift in a direction which tends to increase the temperature. Since the forward reaction is exothermic this means more ammonia will be formed. Thus a low temperature will favour the reaction.

(ii) *Effect of pressure*: If a high pressure is applied on the system, it will shift in a direction which tends to lower the pressure. Since the forward reaction is accompanied by a decrease in volume (4 molecules of reactants give only 2 molecules of ammonia) it will result in more ammonia being formed. Thus a high pressure will favour the reaction.

(ii) *Effect of concentration*: If the concentration of any of the reactants is increased, the system will shift in a direction which tends to lower the concentration. Thus the formation of ammonia will increase. Also, if ammonia is removed from the system in equilibrium the forward reaction will proceed faster to increase the concentration of ammonia.

Q. 14.15 What is catalysis? What are the characteristics of catalysed reactions?

Answer: A substance which alters the speed of a chemical reaction without undergoing any chemical change is known as a *catalyst* and the phenomenon is called *catalysis*. For example, the rate of decomposition of $KClO_3$ increases in the presence of a small quantity of MnO_2.

$$2KClO_3 \xrightarrow{MnO_2} 2KCl+3O_2$$

Here MnO_2 acts as a catalyst.

Other examples are :

$$N_2+3H_2 \xrightarrow{Fe} 2NH_3 \text{ (Haber's process)}$$

$$2SO_2+O_2 \xrightarrow{Pt} 2SO_3$$

General characteristics of catalysed reactions:

(i) The catalyst remains unchanged in chemical composition at the end of the reaction.

(ii) Only a small amount of the catalyst is needed.

(iii) A catalyst does not alter the equilibrium constant or the final equilibrium state of the reacting system.

(iv) A catalyst does not start or initiate a reaction, but it merely increases or decreases its speed.

(v) A catalyst is specific in action.

(vi) A catalyst acts best at an optimum temperature.

Q. 14.16 Where are the following substances used as catalysts.

(i) Vanadium pentoxide (V_2O_5).
(ii) Iron mixed with a small amount of molybdenum metal.
(iii) Manganese dioxide (MnO_2).
(iv) Finely divided nickel.

Answer: (i) Vanadium pentoxide is used as a catalyst in the contact process for the manufacture of sulphuric acid.

(ii) Iron mixed with a small amount of molybdenum metal is used as a catalyst in Haber's process for the manufacture of ammonia.

(iii) Manganese dioxide is used as a catalyst in the preparation of oxygen from potassium chlorate.

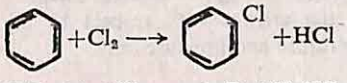
(iv) Finely divided nickel is used as a catalyst for hydrogenation of vegetable oils.

EXERCISES

14.1 Classify the following processes as physical or chemical changes.
(i) Boiling of water.
(ii) Burning of paper.
(iii) Formation of rust on iron.
(iv) Glowing of iron on heating strongly.

(v) Souring of milk.
(vi) Dissolution of sugar in water.
(vii) Burning of wood.
(viii) Decaying of plants.

14.2 Classify the following reactions as (i) combination (ii) decomposition (iii) substitution (iv) double decomposition.

(a) 

(b) $NaBr+AgNO_3 \longrightarrow AgBr+NaNO_3$

(c) $C+2S \longrightarrow CS_2$

(d) $2Cu(NO_3)_2 \longrightarrow 2CuO+4NO_2+O_2$

(e) $CH_3-CH_2-Cl+KOH \longrightarrow CH_3-CH_2-OH+KCl$

(f) $NH_4NO_3 \longrightarrow N_2O+2H_2O$

(g) $2P+5Cl_2 \longrightarrow 2PCl_5$

(h) $2KI+Pb(NO_3)_2 \longrightarrow PbI_2+2KNO_3$

14.3 Give the oxidation number of (i) C in K_2CO_3 (ii) N in N_2H_4 (iii) Ba in BaO_2 (iv) Mn in Na_2MnO_4 (v) Cr in K_2CrO_4.

14.4 In the following reactions, explain: (a) which element is oxidised and which is reduced; (b) which substance acts as an oxidizing agent and which as a reducing agent.

(i) $2KI+Cl_2 \longrightarrow 2KCl+I_2$
(ii) $N_2+3H_2 \longrightarrow 2NH_3$
(iii) $2As_2O_3+MnO_4^- \longrightarrow 2As_2O_5+Mn^{2+}$
(iv) $2FeCl_3+SnCl_2 \longrightarrow 2FeCl_2+SnCl_4$

14.5 Formulate expressions for the equilibrium constant *K* for each of the following:

(i) $2H_2O \rightleftharpoons 2H_2+O_2$
(ii) $2SO_2+O_2 \rightleftharpoons 2SO_3$
(iii) $CO+H_2O \rightleftharpoons CO_2+H_2$
(iv) $Br_2+H_2 \rightleftharpoons 2HBr$

14.6 Mark the following statements as correct or incorrect.

(i) Temperature has no effect on rate of a reaction.
(ii) $PCl_5 \rightleftharpoons PCl_3+Cl_2$ is a reversible reaction.
(iii) $N_2+3H_2 \longrightarrow 2NH_3$+heat, is an endothermic reaction.
(iv) The formation of ammonia is favoured at high pressure.
(v) A catalyst is specific in action.
(vi) For the reversible reaction

$$C+CO_2 \rightleftharpoons 2CO$$

$$K_c = \frac{[CO]^2}{[CO_2]}$$

14.7 Match the statements in column A with those in column B.

COLUMN A

1. A change in which no new substance is formed
2. A change in which new substances with entirely new properties are formed
3. Oxidation is a process of
4. Reactions in which both oxidation and reduction occur simultaneously
5. Reactions that produce heat
6. Combination reactions result in the formation of a
7. Homogeneous reactions are those in which
8. Heterogeneous reactions are those in which
9. The rates of chemical reactions are
10. Vanadium pentoxide is used

COLUMN B

1. reactants and products are in different phases.
2. new substance from simpler substances.
3. reactants and products are in same phase.
4. are called exothermic reactions.
5. loss of electrons.
6. considerably influenced by the temperature.
7. as a catalyst in the contact process.
8. is called a physical change.
9. are called redox reactions.
10. is called a chemical change.

14.8 Draw a line under the most appropriate answer.

1. Burning of coal is a (physical change, chemical change).
2. Chlorine displaces bromine and iodine from a solution of bromide and iodide. This type of reaction is know as (combination, decomposition, substitution).
3. In the reaction $Zn+CuSO_4 \longrightarrow ZnSO_4+Cu$, Cu is (oxidised, reduced).
4. The reaction $NaCl+AgNO_3 \rightarrow NaNO_3+AgCl$ is known as (redox, double decomposition, reversible) reaction.
5. In $N_2+3H_2 \rightleftharpoons 2NH_3$+heat, the formation of ammonia will be favoured at (high temperature, low temperature).
6. Which one of the following reactions is homogeneous?
   (a) $NaOH(aq)+HCl(aq) \longrightarrow NaCl(aq)+H_2O$
   (b) $Zn(s)+2HCl(aq) \longrightarrow ZnCl_2(aq)+H_2(g)$
   (c) $CaCO_3(s) \xrightarrow{heat} CaO(s)+CO_2(g)$
7. The oxidation number of P in H_3PO_4 is (+7, —3, +5, −5).
8. The catalyst used in the manufacture of sulphuric acid is (MnO_2, Fe, V_2O_5, Pt).

14.9 Explain with suitable examples the difference between reversible and irreversible reactions.

14.10 (a) Explain oxidation and reduction. Give examples. (b) Explain the terms oxidizing agent and reducing agent.

14.11 How is the oxidation number of an atom in a compound assigned?

14.12 Explain why the rate of a reaction depends on (i) nature of reactants (ii) concentration (iii) temperature (iv) catalysts.

14.13 Will the following operations increase or decrease the rate of a reaction?
(i) Raising the temperature of the reactants.
(ii) Dissolving the reactants in a common solvent.

14.14 Apply Le Chatelier's principle to predict how the following reversible reaction can be made to take place favouring the formation of AB_3 :

$$A_2(g)+3B_2(g) \rightleftharpoons 2AB_3(g)+\text{heat}$$

Give the answer with respect to the effect of temperature and pressure only.

UNIT 15

Carbon

Carbon is present in group IV A of the periodic table (Fig. 15.1). It has 4 electrons in its valence shell. Carbon is one of the most important elements. Its importance for the life process is very great as it is a constituent of all living matter. Carbon forms over a million compounds. It is the important constituent of all organic compounds.

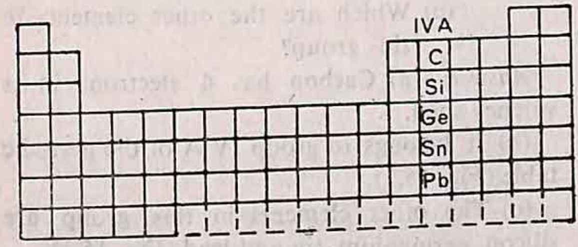


FIG. 15.1

Some of the physical properties of group IVA elements are summarised in Table 15.1.

Carbon exhibits allotropy, its chief allotropes being diamond and graphite. The physical and chemical properties of these are summarised in Table 15.2. Diamond is used in jewellery because of its brilliance and in cutting and drilling equipment because of its hardness. Graphite is chiefly used as a lubricant and in making 'lead' for pencils.

Carbon monoxide and carbon dioxide are important oxides of carbon. Carbon monoxide is a very poisonous gas and causes death by asphyxation (lack of oxygen). Its main use is as a fuel in the form of producer gas and water gas.

Carbon dioxide is neither combustible nor a supporter of combustion. It therefore finds use in fire-extinguishers. Its other important uses are in the manufacture of aerated water and as dry ice (solid CO_2) for cooling foodstuffs.

TABLE 15.1 PHYSICAL PROPERTIES OF GROUP IVA ELEMENTS

	Carbon	*Silicon*	*Germanium*	*Tin*	*Lead*
Symbol	C	Si	Ge	Sn	Pb
Atomic number	6	14	32	50	82
Electronic structure	2,4	2,8,4	2,8,18,4	2,8,18,18,4	2,8,18,32,18,4
Physical state	Solid	Solid	Solid	Solid	Solid
Melting point (K)	4023	1696	1233	505	600
Boiling point (K)	4073	2953	3103	2960	2024
Density (g/cm³)	2.26	2.35	5.36	6.00	11.34

TABLE 15.2 PHYSICAL AND CHEMICAL PROPERTIES OF GRAPHITE AND DIAMOND

Sl. no.	*Property*	*Graphite*	*Diamond*
1.	Colour and appearance	Greyish black, metallic lustre	Colourless, transparent, brilliant
2.	Nature of crystal	Hexagonal, soft and slippery	Tetrahedral, vary hard (hardest natural substance)
3.	Specific gravity	2.3	3.5
4.	Refractive index	—	2.4
5.	Purity	90-97% pure	Purest form of carbon (almost 100% pure)
6.	Conductivity	Good conductor of heat and electricity	Bad conductor of heat and electricity
7.	Effect of heat	Burns in air at 973 K giving CO_2	Burns in oxygen at 1173 K giving CO_2
8.	Solubility	Does not dissolve in ordinary solvents	Does not dissolve in ordinary solvents
9.	Effect of acids and alkalies	Not attacked except by conc. HNO_3 which gives graphitic acid	Not attacked
10.	Reaction with halides	Forms CF_4 with F_2 at high temp.	Forms CF_4 with F_2 at high temp.

Q. 15.1 Discuss the occurence of carbon in nature. Why is it considered to be such an important element?

Answer: Carbon is abundant in nature and is found in both the free and the combined states. In the free state it occurs as diamond and graphite in crystalline form, and as coal in amorphous form. In the combined state it occurs in the atmosphere as carbon dioxide. In the earth's crust it is present in rocks as carbonates of calcium, etc. It is a major constituent of petroleum and natural gas. Combined with hydrogen and oxygen, alongwith other elements such as phosphorus, nitrogen, etc. it forms several compounds such as carbohydrates, proteins, fats, oils, etc.

Carbon is one of the most important elements. Its importance for the life process is very great as it is found in all living things, and in all compounds necessary for life such as carbohydrates, proteins, fats, starches, vitamins, oils, etc. Carbon is the most important constituent of the natural resources of fuel such as petroleum, natural gas and coal. Carbon forms over a million compounds—more than the total number of compounds formed by all other elements.

Q. 15.2 (a) How many electrons does carbon have in its valency shell?
(b) To which group in the periodic table does carbon belong?
(c) Which are the other elements in this group?

Answer: (a) Carbon has 4 electrons in its valency shell.

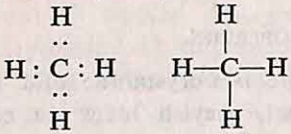
(b) It belongs to group IV A of the periodic table (Fig. 15.1).

(c) The other elements in this group are silicon, germanium, tin and lead (Fig. 15.1).

Q. 15.3 Why does carbon form covalent bonds with itself and other elements? What is the tetrahedral model of the carbon atom?

Answer: Carbon has 4 electrons in its valency shell. It can therefore attain a stable structure either by losing 4 electrons and acquiring the helium configuration or by gaining 4 electrons to acquire the neon configuration. However, both these processes are not easy because of the accompanying large energy changes. Hence, carbon completes its octet by sharing its four valence electrons with itself or with other elements. Thus carbon always forms covalent compounds and its covalency is 4, i.e. it is *tetravalent* in nature.

Example : Methane, CH_4



$$\begin{array}{ccccc} & & H & & \\ & & \cdot\cdot & & \\ H & : & C & : & H \\ & & \cdot\cdot & & \\ & & H & & \end{array} \qquad \begin{array}{ccc} & H & \\ & | & \\ H- & C & -H \\ & | & \\ & H & \end{array}$$

The four covalent bonds of a carbon atom are symmetrically distributed in three dimensions. The bonds are directed towards the vertices of a regular tetrahedron making an angle of 109° 28′ with each other (Fig. 15.2).

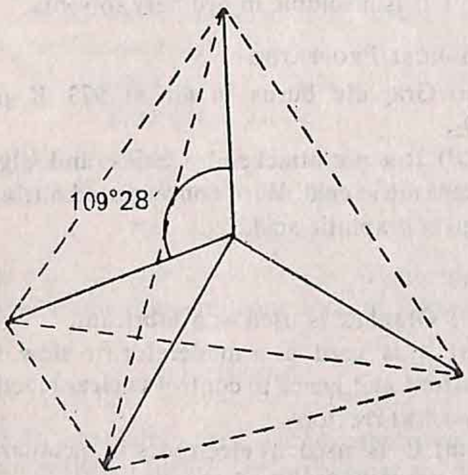


FIG. 15.2 Tetrahedral model of the carbon atom.

This is known as the tetrahedral model of the carbon atom.

Q. 15.4 (i) What is allotropy?

(ii) What are the chief allotropic forms of carbon? Give their structures. What physical properties do diamond and graphite have on account of their structure.

(iii) Name two other elements, besides carbon, that show allotropy.

Answer: (i) Allotropy is the property by virtue of which an element possesses different physical forms.

(ii) The chief allotropic forms of carbon are graphite and diamond.

Diamond: In diamond each carbon atom is covalently bonded to four other carbon atoms at the corners of a regular tetrahedron. These four atoms in turn form the centre of other similar tetrahedrons. Thus this pattern is repeated indefinitely in three dimension (Fig. 15.3).

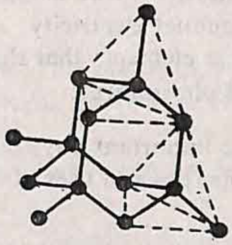


FIG. 15.3 Structure of diamond. The dotted lines show tetrahedral arrangements of carbon atoms.

The strong covalent bonding in diamond is the cause of its hardness, its resistance to chemical attack, its high vaporization temperature (3773 K) and its high density. Also, since none of the valence electrons in diamond are free, it is a bad conductor of electricity.

Graphite: Graphite consists of several layers of carbon atoms, each one atom thick. Within each layer the carbon atoms are strongly bonded together by covalent bonds forming hexagonal rings (Fig. 15.4). There is no covalent bond between adjacent layers. These layers are bonded together by weak forces known as van der Waal's forces. The layers can therefore

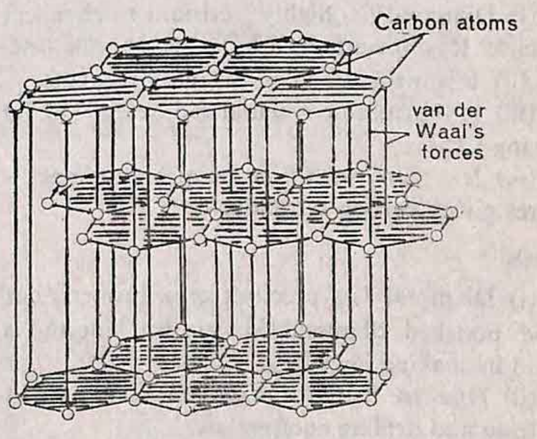


FIG 15.4 Structure of graphite.

easily slip over one another. This is the reason for the softness and lubricating power of graphite. In graphite since only three of the four carbon electrons are used to form covalent bonds one electron is free to move. Graphite can therefore conduct electricity.

(iii) Two other elements that show allotropy are sulphur and phosphorus.

Q. 15.5 List the important physical and chemical properties and uses of diamond.

Answer

PHYSICAL PROPERTIES

(i) Diamond is a crystalline solid. Its crystals are octahedral, colourless and transparent.

(ii) It is the hardest of all natural substances.

(iii) Its density is 3.5 and it vaporizes at 3773 K. It does not melt due to the strong C–C bonds.

(iv) It has a high refractive index of 2.4. This is the reason for its brilliance. The brilliance is further enhanced by cutting it at certain angles to obtain maximum reflection of light.

(v) It is a non-conductor of heat and electricity.

CHEMICAL PROPERTIES

(i) Diamond is highly resistant to chemical attack. It is not attacked by acids and alkalies.

(ii) It is insoluble in all ordinary reagents.

(iii) It burns in oxygen at red heat (1173 K) giving CO_2.

(iv) It reacts with flourine at high temperatures giving carbon tetraflouride (CF_4).

USES

(i) Diamond is a precious gem. Properly cut and polished diamond is very brilliant and is used in making jewellery.

(ii) Due to its hardness, diamond is used in cutting and drilling equipments.

(iii) It is used in making moulds for drawing very thin metal wires.

Q. 15.6 List the important physical and chemical properties and uses of graphite.

Answer

PHYSICAL PROPERTIES

(i) Graphite is a crystalline solid. Its crystals are hexagonal, greyish black in colour and slippery.

(ii) It has a metallic lustre.

(iii) Its density is 2.3 g/cm³.

(iv) It is a good conductor of heat and electricity.

(v) It is insoluble in ordinary solvents.

CHEMICAL PROPERTIES

(i) Graphite burns in air at 973 K giving CO_2.

(ii) It is not attacked by acids and alkalies except nitric acid. With concentrated nitric acid it gives graphitic acid.

USES

(i) Graphite is used as a lubricant.

(ii) It is used as a moderator (to slow down neutrons and hence to control nuclear reactions) in nuclear reactors.

(iii) It is used as electrodes in metallurgical processes and in electric furnaces.

(iv) It is used in making 'lead' pencils after hardening with clay.

(v) It is used in making crucibles for metallurgical processes.

Q. 15.7 (i) How many oxides are formed by carbon?

(ii) What products are obtained when carbon is burnt in: (a) limited supply of air (b) sufficient supply of air.

Answer: Carbon forms two major oxides (i) carbon monoxide, CO (ii) carbon dioxide, CO_2.

If carbon is burnt in a limited supply of air carbon monoxide is formed.

$$2C + O_2 \rightarrow 2CO$$

In sufficient supply of air or in oxygen, CO_2 is formed.

$$C + O_2 \rightarrow CO_2$$

Q. 15.8 How can carbon monoxide be prepared from (i) carbon (ii) carbon dioxide (iii) formic acid (iv) oxalic acid? Describe the method used in the laboratory preparation of carbon monoxide.

Answer: (i) Carbon monoxide can be prepared by heating carbon in a limited supply of air.

$$2C + O_2 \rightarrow 2CO$$

It can also be obtained by heating carbon with metallic oxides such as iron oxide, zinc oxide, copper oxide, etc.

$$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$$
$$ZnO + C \rightarrow Zn + CO$$

(ii) When carbon dioxide is passed over heated carbon, it is reduced to carbon monoxide.

$$CO_2 + C \rightarrow 2CO$$

(iii) Carbon monoxide can be obtained by heating formic acid with concentrated sulphuric acid.

$$HCOOH \xrightarrow{\text{conc. } H_2SO_4} CO + H_2O$$

(iv) In the laboratory, carbon monoxide is usually prepared by heating oxalic acid crystals with concentrated sulphuric acid at about 333 K. Both carbon dioxide and carbon monoxide are formed.

$$\begin{array}{c} COOH \\ | \\ COOH \end{array} \xrightarrow{\text{conc. } H_2SO_4} CO + CO_2 + H_2O$$

Carbon dioxide is removed by passing the mixture of gases through caustic potash solution. Carbon monoxide is collected by displacement of water. The apparatus used is shown in Fig. 15.5.

Q. 15.9 Give the important physical and chemical properties of carbon monoxide.

Answer: (i) Carbon monoxide is a colourless and odourless gas.

(ii) It is very slightly soluble in water.

(iii) It is neutral to litmus.

(iv) It is extremely poisonous.

(v) It burns in air with a blue flame.

$$2CO + O_2 \rightarrow 2CO_2$$

(vi) At high pressure and at 473 K it combines with sodium hydroxide forming sodium formate.

$$CO + NaOH \rightarrow HCOONa$$

(vii) At high temperature and pressure, and in the presence of a catalyst, it combines with hydrogen to form methanol.

$$CO + 2H_2 \rightarrow CH_3OH$$

Q. 15.10 List some important uses of carbon monoxide.

Answer: Some of the important uses of carbon monoxide are as follows.

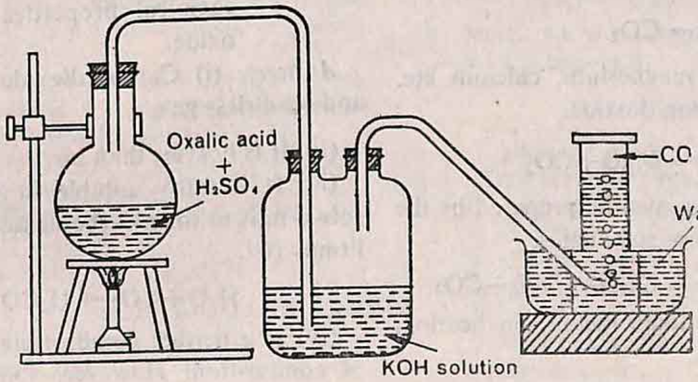


FIG. 15.5 Preparation of carbon monoxide.

(i) In the manufacture of methyl alcohol.

(ii) As a fuel, especially in the form of water gas ($CO+H_2$) and producer gas (N_2+CO).

(iii) In the preparation of phosgene ($COCl_2$), a poisonous gas used in warfare and in the dye industry.

(iv) In some metallurgical processes as a reducing agent.

(v) In the metallurgy of nickel for the purification of the metal.

Q. 15.11 Discuss the poisonous nature of carbon monoxide.

Answer: Carbon monoxide is an extremely poisonous gas and as little as 1% of the gas in air can prove fatal. It is particularly dangerous as it has no smell and hence cannot be easily detected.

Oxygen is carried through all parts of the body by haemoglobin present in the blood. When a person inhales carbon monoxide, it combines with haemoglobin to form carboxyhaemoglobin which is incapable of absorbing any more oxygen. The person therefore dies due to lack of oxygen.

Q. 15.12 How can you prepare carbon dioxide from (a) carbon (b) carbonates (c) bicarbonates. Describe the method commonly used in the laboratory.

Answer: (a) Carbon dioxide can be prepared by heating carbon in excess of air.

$$C+O_2 \rightarrow CO_2$$

(b) Carbonates of magnesium, calcium, etc. when heated give carbon dioxide.

$$MgCO_3 \rightarrow MgO+CO_2$$

Carbon dioxide can also be prepared by the action of dilute acids on carbonates.

$$CaCO_3+2HCl \rightarrow CaCl_2+H_2O+CO_2$$

(c) Bicarbonates of alkali metals, on heating, give CO_2.

$$2NaHCO_3 \rightarrow Na_2CO_3+H_2O+CO_2$$

The action of dilute acids on bicarbonates also gives carbon dioxide.

$$NaHCO_3+HCl \rightarrow NaCl+H_2O+CO_2$$

Laboratory method: In the laboratory, carbon dioxide is prepared by the action of dilute hydrochloric acid on marble chips ($CaCO_3$).

$$CaCO_3+2HCl \rightarrow CaCl_2+H_2O+CO_2$$

The apparatus used is shown in Fig. 15.6. Carbon dioxide being heavier than air, is collected by upward displacement of air.

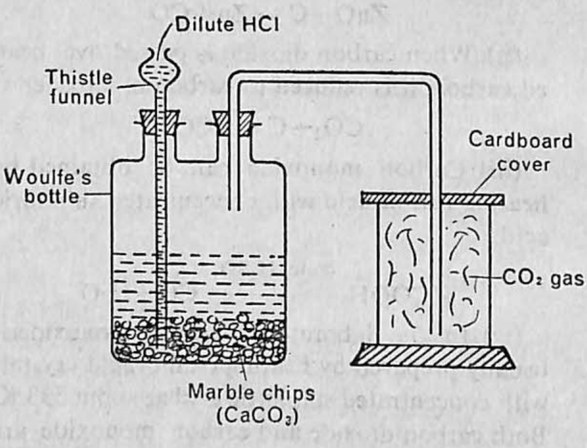


FIG. 15.6 Preparation of carbon dioxide.

Q. 15.13 Give the important physical and chemical properties of carbon dioxide.

Answer: (i) Carbon dioxide is a colourless and odourless gas.

(ii) It is heavier than air.

(iii) It is fairly soluble in water, and dissolves in it to form carbonic acid. It turns blue litmus red.

$$H_2O+CO_2 \rightarrow H_2CO_3$$

(iv) It is neither combustible nor a supporter of combustion. However, some active metals such as magnesium continue to burn in it.

$$2Mg+CO_2 \rightarrow 2MgO+C$$

(v) When passed over red hot coke, it is reduced to carbon monoxide.

$$CO_2+C \rightarrow 2CO$$

(vi) When it is passed through lime water it turns milky due to the formation of insoluble calcium carbonate.

$$Ca(OH)_2+CO_2 \rightarrow CaCO_3+H_2O$$

On passing more carbon dioxide the milkiness disappears due to the formation of soluble calcium bicarbonate.

$$CaCO_3+CO_2+H_2O \rightarrow Ca(HCO_3)_2$$

On boiling this clear solution, the milkiness reappears as calcium bicarbonate decomposes to form calcium carbonate.

$$Ca(HCO_3)_2 \rightarrow CaCO_3+H_2O+CO_2$$

(vii) Being acidic in nature it neutralises alkalies to give two salts, carbonate and bicarbonate.

$$2NaOH+CO_2 \rightarrow Na_2CO_3+H_2O$$
$$Na_2CO_3+H_2O+CO_2 \rightarrow 2NaHCO_3$$

(viii) It reacts with basic oxides forming the corresponding salts.

$$CaO+CO_2 \rightarrow CaCO_3$$
$$Na_2O+CO_2 \rightarrow Na_2CO_3$$

Q. 15.14 Give some important uses of carbon dioxide.

Answer: The important uses of carbon dioxide are as follows.

(i) In the manufacture of aerated waters and drinks.

(ii) In soda-acid fire extinguishers, carbon dioxide is produced and used to extinguish fires.

(iii) Solid carbon dioxide, known as dry ice, is used as a coolant in stores, trucks and freight cars for transporting foodstuffs.

(iv) In the manufacture of sodium carbonate by Solvay's process.

(v) Powdered dry ice has also been used in cloud-seeding techniques for artificial production of rain.

(vi) Plants use carbon dioxide to make food through the process of photosynthesis.

(vii) In baking cakes and bread.

EXERCISES

15.1 Name some compounds of carbon which are useful in our daily life.

15.2 Why can carbon not form electrovalent compounds?

15.3 Give two chemical reactions each of carbon acting as oxidising and reducing agent respectively.

15.4 Explain (a) carbon invariably forms covalent bonds; (b) hardness or softness of substances is related to their crystalline structures.

15.5 How many allotropes does carbon have? Name them and give their structures.

15.6 CO_2 is absorbed more in NaOH than in pure water. Why?

15.7 What happens when:

(i) Formic acid is heated with concentrated H_2SO_4.
(ii) Oxalic acid is heated with concentrated H_2SO_4.
(iii) CO_2 is passed through lime water.
(iv) Copper oxide is heated with carbon.
(v) Burning Mg is introduced in a jar of CO_2.
(vi) Carbonate of a metal is heated.
(vii) Steam is passed over red hot carbon.
(viii) CO_2 is passed through KOH solution.

15.8 Match the terms/statements in column A with those in column B.

COLUMN A

1. Carbon contains
2. Carbon shows allotropy
3. Diamond and graphite are
4. Diamond is the purest and hardest
5. Graphite is a good conductor of
6. Carbon monoxide is prepared by
7. Carbon dioxide is prepared by
8. Diamond is used
9. Graphite is used
10. Carbon monoxide is used
11. Carbon dioxide is used

COLUMN B

1. for extinguishing fires.
2. the action of dilute acids on bicarbonates.
3. in metallurgy as a reducing agent.
4. as a dry lubricant.
5. heat and electricity.
6. in cutting instruments.
7. form of carbon.
8. the only crystalline allotropes of carbon.
9. because it exists in different forms.
10. four electrons in its valence shell.
11. the dehydration of formic acid.

15.9 Draw a line under the most appropriate answer.

1. In the periodic table carbon is the first member of group (IV A, IV B, V A).
2. Plants inhale carbon dioxide during (daytime, nightime).
3. The gas used in the manufacture of sodium carbonate and sodium bicarbonate by the Solvay's process is (CO_2, CO).
4. Diamonds and graphite are (crystalline, amorphous).
5. When CO_2 gas is passed through lime water it becomes (milky, red).

15.10 Why is carbon so important for the life process?

15.11 Why does diamond find use in industry?

15.12 Compare and contrast the behaviour of graphite and diamond with reference to their structures.

15.13 Why is carbon monoxide regarded as very dangerous?

15.14 How can carbon monoxide be separated from a mixture of carbon monoxide and carbon dioxide?

15.15 How is CO_2 used in extinguishing a fire?

15.16 What is dry ice? Where is it used?

UNIT 16

Fuels

D. 16.1 Fuel: Substance which is burnt to produce heat energy.

D. 16.2 Destructive distillation of wood (or coal): Heating of wood (or coal) in the absence of air.

D. 16.3 Charcoal: Residue left after destructive distillation of wood.

D. 16.4 Coke: Amorphous allotropic form of carbon obtained by destructive distillation of coal.

D. 16.5 Coal gas: Gaseous fuel mainly containing methane, hydrogen and carbon monoxide.

D. 16.6 Water gas: Gaseous fuel containing carbon monoxide and hydrogen.

D.16.7 Producer gas: Gaseous fuel containing carbon monoxide and nitrogen.

D. 16.8 L.P.G.: Liquefied petroleum gas. A fuel containing mixture of propane, butane and iso-butane.

D.16.9 Propellant: The combustible substance in a rocket fuel.

D. 16.10 Oxidant: The substance in a rocket fuel that provides oxygen for combustion.

D. 16.11 Calorific value: Amount of heat produced in calories or kilocalories by burning a unit mass of the fuel.

D. 16.12 Combustion: Chemical reaction accompanied by the evolution of heat and light.

D. 16.83 Combustible substance: That which can burn to produce heat and light.

D. 16.14 Supporter of combustion: That which does not burn itself but supports combustion of other substances.

D. 16.15 Ignition (or kindling) temperature: Lowest temperature at which a substance catches fire.

D. 16.16 Rapid combustion: In which the fuel starts burning immediately on ignition.

D. 16.17 Spontaneous combustion: Which does not require the application of external heat for combustion.

D.16.18 Explosion: A combustion where large amount of gases with the evolution of tremendous amount of heat energy and light are produced.

D. 16.19 Heat of combustion: The amount of heat liberated when one mole of a substance burns completely.

D.16.20 Calorific value(of a fuel): The amount of heat obtained by burning one gram of the fuel.

Q. 16.1 (i) What is a fuel?
(ii) Give the characteristics of a good fuel.
(iii) Name the different types of fuels and give three examples of each.

Answer: (i) A substance which is burnt for producing heat energy is called a fuel.

(ii) A good fuel must have the following properties.

(1) Cheap

(2) Readily available.

(3) Easy to transport, store and handle.

(4) Combustible in a controlled way.

(5) Should not produce harmful products on burning.

(6) Should not leave a large amount of ash.

(7) High calorific value.

(iii) A fuel can exist in three states. Solid fuel, e.g. coal, wood, paraffin wax. Liquid fuel, e.g. kerosene oil, petrol, alcohol. Gaseous fuel, e.g. natural gas, coal gas, acetylene.

Q. 16.2 What are the advantages and disadvantages of solid fuels? Which are the commonly used solid fuels? Discuss their availability, advantages and disadvantages.

Answer: Solid fuels are available in large quantities. They are easy to transport, store and handle. However, some of them (coal and wood) leave a large amount of ash.

The commonly used solid fuels are wood, charcoal, coal, coke and paraffin wax.

(i) *Wood*: Trees are the source of wood. It contains compounds of carbon, hydrogen and oxygen. As trees grow rapidly this is a renewable source of energy. However, it leaves a large amount of ash when burnt.

(ii) *Charcoal*: Charcoal is produced by heating wood in the absence of air (destructive distillation of wood). It is mainly carbon. It burns without producing smoke and is therefore an important fuel for domestic purposes. It leaves little ash and is also easy to transport, store and handle. However it is somewhat expensive.

(iii) *Coal*: Coal is a naturally occurring mineral found under the earth's crust. It is formed from dead plants and trees by a natural process which takes millions of years. It is a black coloured solid consisting mainly of carbon. Coal is cheap, available in large quantities and easy to transport, store and handle. However, it gives out a lot of smoke and leaves ash when burnt.

(iv) *Coke*: It is obtained by heating coal in the absence of air (destructive distillation of coal). It consists mainly of carbon. It gives less smoke than coal.

(v) *Paraffin wax*: It is obtained as a by-product of petroleum refining. It is a mixture of hydrocarbons.

Q. 16.3 Which are the commonly used liquid fuels? How are they obtained? Discuss their availability, uses, advantages and disadvantages.

Answer: The commonly used liquid fuels are kerosene oil, petrol, diesel and ethyl alcohol (spirit). The first three are obtained by fractional distillation of petroleum. Ethyl alcohol is obtained by fermentation of sugar or starch.

(i) *Kerosene oil*: It is a colourless liquid consisting of a mixture of hydrocarbons. It is an important domestic fuel as it is not as inflammable as petrol and is therefore easier to store.

(ii) *Petrol*: It is a colourless liquid consisting of a mixture of hydrocarbons. Being highly inflammable it is difficult to transport, store and handle. It is chiefly used as a fuel in automobiles.

(iii) *Diesel*: It is a yellowish liquid and is also a mixture of hydrocarbons. It is extensively used in automobiles, pumps and railway engines.

(iv) *Ethyl alcohol*: It is a highly inflammable liquid and burns with a blue, smokeless flame. It is mainly used in laboratories as fuel in spirit lamps.

Q. 16.4 What are the advantages and disadvantages of gaseous fuels? Which are the commonly used gaseous fuels? Discuss their availability and uses.

Answer: Gases are very useful as fuels as they produce a large amount of heat and burn without leaving ash or producing smoke. However, they are difficult to store, transport and handle because of their highly inflammable nature. Also, a special device is needed to burn them.

The commonly used gaseous fuels are natural gas, coal gas, producer gas, water gas, domestic gas (or liquefied petroleum gas, LPG) and acetylene.

(i) *Natural gas*: It occurs naturally under the earth's crust in association with petroleum and consists mainly of methane. It is a good non-poisonous fuel.

(ii) *Coal gas*: It is obtained by destructive distillation of coal and consists mainly of methane, hydrogen and carbon monoxide. Because of the presence of carbon monoxide it is poisonous.

(iii) *Producer gas*: It is obtained by passing air over red hot coke, and is a mixture of carbon monoxide and nitrogen.

$$C + \text{air} \longrightarrow CO + N_2$$

It is poisonous due to the presence of carbon monoxide.

(iv) *Water gas*: It is obtained by passing steam over red hot coke, and is a mixture of carbon monoxide and hydrogen.

$$C + H_2O \longrightarrow CO + H_2$$

It is poisonous due to the presence of carbon monoxide.

(v) *Domestic gas or liquefied petroleum gas (LPG)*: It is obtained as a by-product of petroleum refining. Its main constituents are propane and butane. It is used as a domestic fuel. It is stored in a liquefied form under high pressure. It is highly inflammable.

(vi) *Acetylene* (C_2H_2): It is manufactured by the action of water on calcium carbide.

$$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2$$

It is mainly used in oxy-acetylene torches which are used for cutting and welding.

Q. 16.5 What are the requirements of a rocket fuel? Name some solid and liquid rocket fuels.

Answer: A rocket fuel

(i) must occupy less space.

(ii) should not use atmospheric oxygen for combustion.

Because of the second requirement a rocket fuel must have its own oxygen supply. It therefore consists of a *propellant* (which burns) and an *oxidant* (which provides oxygen for burning).

(a) *Solid propellants*: These are mixtures of oxidizing and reducing agents. Common solid propellants are polybutadiene, aluminium powder and acrylic acid. Common oxidants are chlorates, perchlorates and nitrates of some metals (e.g. Al).

(b) *Liquid propellants*: These consist of a liquid oxidizer like oxygen or nitric acid. The common combinations are :

(i) Liquid hydrogen and liquid oxygen.

(ii) Kerosene oil and liquid oxygen.

Q. 16.6 (i) What is combustion?

(ii) How are oxidation and combustion related?

(iii) Is oxygen a necessary requirement for combustion? Explain giving examples.

(iv) What is the difference between a combustible substance and a supporter of combustion?

Answer: (i) Combustion is a chemical reaction which occurs with the evolution of heat and light.

Example : burning of coal, wood, fuel gases, etc. in air or oxygen.

$$C + O_2 \longrightarrow CO_2 + \text{heat} + \text{light}$$
$$CO + O_2 \longrightarrow 2CO_2 + \text{heat} + \text{light}$$

(ii) Oxidation is a process of combination of a substance with oxygen or any other electronegative element. Oxidation may or may not be accompanied by the evolution of heat. Combustion also involves oxidation, but the oxidation in this case must be accompanied by evolution of heat.

(iii) Oxygen is not a necessary requirement for combustion. Thus, for example, hydrogen and antimony can burn in an atmosphere of chlorine.

$$H_2+Cl_2 \longrightarrow 2HCl+\text{heat}+\text{light}$$
$$2Sb+3Cl_2 \longrightarrow 2SbCl_3+\text{heat}+\text{light}$$

(iv) A combustible substance is that which can burn to produce heat and light, e.g. paper, wood, coke, LPG, etc. Supporters of combustion are substances which do not burn themselves but support combustion of other substances, e.g. oxygen.

Q. 16.7 What conditions are necessary for the combustion of a substance?

Answer: Before a substance can be made to burn, three conditions must be fulfilled. These are:

(i) Presence of a combustible substance such as paper, kerosene oil, coal, etc.

(ii) Presence of a supporter of combustion, such as oxygen or air.

(iii) Attainment of the lowest temperature at which the substance burns rapidly without further addition of heat from outside, i.e. attainment of the kindling or ignition temperature.

Q.16.8 (i) How many different types of combustion are known? Illustrate your answer with suitable examples.
(ii) Define ignition temperature.

Answer: (i) Combustion is generally of three different types.

(a) *Rapid combustion*: In this combustion process the fuel starts burning immediately on ignition. This includes oxidation reactions in which large amounts of heat and light are produced in a short time, e.g. burning of fuel gases, candles, etc.

(b) *Spontaneous combustion*: This type of combustion does not require the application of any external heat, e.g. white phosphorus burns spontaneously in air.

(c) *Explosion*: Explosions occur when a very rapid oxidation of chemicals results in liberation of large volumes of gases together with heat and light released in huge amount, e.g. firing of a gun-shot.

(ii) The lowest temperature at which a substance begins to burn is called its ignition or kindling temperature.

Q.16.9 Explain the following giving examples.
(i) Heat of combustion.
(ii) Calorific value of a fuel.

Answer: (i) The process of burning in oxygen with liberation of heat and light is called combustion. The amount of heat liberated when one mole of a substance burns completely, is called the heat of combustion of that substance, e.g. 212.7 k cal of heat is given out when 1 mole of methane is burnt. Therefore the heat of combustion of methane is 212.7 k cal.

$$CH_4+3O_2 \rightarrow CO_2+2H_2O+212.7 \text{ k cal}$$

(ii) Calorific value of a fuel is the amount of heat obtained by burning one gram of that fuel. 1 mole of carbon (at. wt. = 12) produces 94.0 k cal of heat.

$$C+O_2 \rightarrow CO_2+94.0 \text{ kcal}$$

Hence, the calorific value of carbon is 94/12 = 7.83 k cal.

Q.16.10 Explain how spontaneous combustion occurs?

Answer: Spontaneous combustion does not require the application of any external heat. In this type of combustion, the particles of the combustible substance get oxidized by the oxygen of air with the evolution of some heat. This heat gets accumulated till the ignition temperature of the combustible substance is reached. At this point the substance spontaneously catches fire, e.g. a piece of filter paper, dipped in a solution of phosphorus in carbon disulphide, bursts into flames when waved slowly in air.

Q.16.11 Explain why (i) a burning magnesium ribbon burns more brightly in oxygen than in air; (ii) wood shavings ignite more rapidly than a log of wood.

Answer: (i) Due to the plentiful supply of oxygen the oxidation of magnesium proceeds much faster. Hence the ribbon burns more rapidly in pure oxygen than in air.

(ii) Wood shavings being small require less heat to reach their ignition temperature than a log of wood.

Q.16.12 (i) By what methods can a fire be extinguished?

(ii) How does water put out fires? Why can it not be used to extinguish kerosene oil, petrol and electrical fires?

(iii) Describe the principle, construction, working and uses of

(a) Soda-acid fire extinguisher

(b) Foam-type fire extinguisher

(c) Carbon-tetrachloride fire extinguisher.

Answer (i) A fire can be extinguished by the following methods.

(a) By removing the combustible substances.

(b) By cutting off the air supply and thus smothering the fire.

(c) By cooling the fire so that the temperature of the combustible substances falls below their ignition temperature.

(ii) *Water* (Principle: cooling of fire): When water is thrown over a fire, it is extinguished because the combustible substances are cooled below their ignition temperature. Also, water vapours surround the combustible substances and cut off the supply of air.

Water is used to extinguish burning wood, coal, clothes, paper, etc. It is not used to extinguish kerosene oil or petrol fires. Being heavier than these substances water forms a lower layer and kerosene and petrol continue burning on top. Water is also not used for electrical fires as it is a conductor of electricity and can give an electric shock to the person throwing or coming in contact with the water.

(iii) (a) *Soda-acid fire extinguisher* (Principle: cooling of fire and increasing CO_2 in the atmosphere): This contains a glass bottle of dilute sulphuric acid supported in a metallic container filled with sodium bicarbonate solution (Fig. 16.1). On pressing hard the knob, the acid bottle breaks and carbon dioxide is liberated.

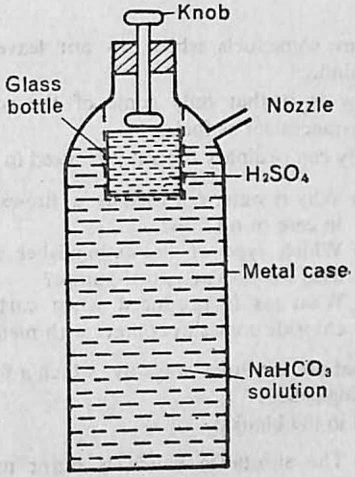


FIG. 16.1 Soda-acid fire extinguisher.

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$$

Due to the pressure of carbon dioxide the solution is thrown out with considerable pressure. Besides cooling the fire, it increases carbon dioxide, a non supporter of combustion, in the atmosphere, and thus extinguishes the fire.

The soda-acid extinguisher is used to extinguish burning wood, coal, clothes, paper, etc. It is not used for fire caused by kerosene oil or petrol. It is also not used for electrical fires.

(b) *Foam-type fire extinguishers* (Principle: smothering of fire): This is similar in construction to the soda-acid extinguisher. It also contains a glass bottle containing dilute sulphuric acid in a metallic container. The sodium bicarbonate solution contains a foaming agent like

Turkey Red Oil. Here carbon dioxide is liberated in the form of a foam which covers the fire and cuts off the air supply, thus extinguishing the fire.

Foam-type fire extinguishers are useful for putting off kerosene oil and petrol fires.

(c) *Carbon tetrachloride fire extinguisher* (Principle: smothering of fire): This extinguisher contains carbon tetrachloride (CCl_4), a highly volatile organic solvent. On being pumped out, the liquid vaporises and, since it is heavier than air, envelops the fire. This cuts off the supply of air and the fire is extinguished. This is useful in fires caused by electricity.

This extinguisher should not be used in a closed room because CCl_4 vapours may produce a poisonous gas, phosgene $COCl_2$, on coming in contact with metals.

EXERCISES

16.1 Name some fuels which do not leave any ash behind.

16.2 Why is it that only some of the combustible substances act as fuels?

16.3 Why can ordinary fuels not be used in rockets?

16.4 (i) Why is water not used as a fire-extinguisher in case of oil fires?
(ii) Which type of fire-extinguisher should be used for fires at petrol-pumps?
(iii) What gas is produced when carbon tetrachloride comes in contact with metals.

16.5 What are the three ways by which a fire can be extinguished?

16.6 Fill in the blanks:

(i) The substance which is burnt to produce heat energy is called......
(ii) Wood is a......fuel, petrol is......fuel and coal gas is a......fuel.
(iii) Wood charcoal is obtained by......
(iv) Rocket fuels are called......
(v) A fire can be extinguished by lowering the temperature of the combustible substance below its......
(vi) The efficiency of a fuel is measured by its...... value.
(vii) Oil fire should not be extinguished by throwing......on it.

16.7 Match the entries in column A with those in column B.

COLUMN A

1. Fuels are substances
2. Coal gas is a mixture of
3. Water gas is a mixture of
4. Producer gas is a mixture of
5. Kindling temperature is the
6. Fuels for rockets
7. Combustion is a chemical reaction
8. Substances which burn with an explosion
9. Spontaneous combustion is combustion
10. Sodium bicarbonate is used

COLUMN B

1. as a fire extinguisher.
2. are termed as explosives.
3. which takes place without any external heat.
4. which occurs with the evolution of heat and light.
5. carbon monoxide and nitrogen.
6. carbon monoxide and hydrogen.
7. methane, hydrogen and carbon monoxide.
8. which produce heat energy on burning.
9. lowest temperature at which a substance catches fire.
10. are called propellants.

16.8 Draw a line under the most appropriate answer.

1. The highest calorific value fuel is (wood, coal, petrol).
2. The fuel used in jet aeroplanes is (diesel, petrol, alcohol).
3. The fuel used for cutting and welding iron is (acetylene, petrol, diesel, coal).
4. A burning matchstick extinguishes when brought near a jar containing(N_2, CO, CO_2).
5. To extinguish oil fires, the extinguisher which works best is (soda-acid type, foam type solid sodium bicarbonate).
6. Soda-acid type fire extinguishers contain dilute (HNO_3, HCl, H_2SO_4).
7. A mixture of propane (C_3H_8) and butane (C_4H_{10}) is known as (producer gas, water gas, LPG, coal gas).

16.9 What is destructive distillation of coal? Which fuel do you get from this?

16.10 Define the term combustion. Is combustion restricted to reactions involving oxygen?

16.11 What is the main distinction between combustion and oxidation?

16.12 What do you understand by kindling (or ignition) temperature?

16.13 Define calorific value of a fuel. What is its importance?

16.14 What principle works in extinguishing a fire with foam-type fire extinguisher?

UNIT 17

Compounds of Carbon

D. 17.1 Organic chemistry : The study of the chemistry of carbon compounds.

D. 17.2 Catenation : The property by virtue of which carbon atoms can combine with other carbon atoms almost endlessly and in a number of ways.

D. 17.3 Isomerism : The property by virtue of which two or more compounds can possess the same molecular formula but different properties, on account of differences in their structures.

D. 17.4 Hydrocarbons : Compounds containing only carbon and hydrogen.

D. 17.5 Saturated hydrocarbons : Those having only single bonds.

D. 17.6 Unsaturated hydrocarbons : Those having at least one double or triple bond.

D. 17.7 Aromatic hydrocarbons : Those having at least one benzene ring.

D. 17.8 Aliphatic hydrocarbons : Those having open chains of carbon atoms.

D. 17.9 Alicyclic hydrocarbons : Those having a ring structure but resembling aliphatic hyrocarbons in their properties.

D. 17.10 Polymerisation : Joining up of a large number of molecules of a similar type to give a molecule with high molecular weight.

D. 17.11 Alkyl radical (*or group*) : Obtained by removing a hydrogen atom from an aliphatic hydrocarbon.

D. 17.12 Aryl radical (*or group*) : Obtained by removing a hydrogen atom from the benzene ring of an aromatic hydrocarbon.

D. 17.13 Functional group : An atom or group of atoms that combines with an alkyl or aryl radical to form a compound. It determines the chemical behaviour of the compound.

D. 17.14 Homologous series : A series containing organic compounds of same class having similar chemical properties but with different molecular formulae.

D. 17.15 Alkanes : Saturated hydrocarbons having the general formula C_nH_{2n+2}.

D. 17.16 Alkenes : Unsaturated hydrocarbons with double bond having the general formula C_nH_{2n}.

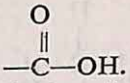
D. 17.17 Alkynes : Unsaturated hydrocarbons with triple bond having the general formula C_nH_{2n-2}.

D. 17.18 Halogen group : The functional groups $-Cl$, $-Br$, $-I$.

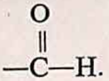
D. 17.19 Hydroxy (*alcoholic*) *group* : The functional group $-OH$.

D. 17.20 Amino group : The functional group $-NH_2$.

D. 17.21 Carboxy (*carboxylic*) *group* : The

functional group 
$-\overset{O}{\overset{\|}{C}}-OH$.

D. 17.22 Keto (carbonyl) group : The functional group $>C=O$.

D. 17.23 Aldehyde group : The functional group 
$-\overset{O}{\overset{\|}{C}}-H$.

D. 17.24 Ester group : The functional group —COOR (where R is an alkyl radical).

D. 17.25 Nitro group : The functional group $-NO_2$.

D. 17.26 Petroleum : A black viscous liquid occurring under the earth's crust and consisting of a mixture of a large number of hydrocarbons.

D. 17.27 Refining of petroleum : Process by which various useful products are separated from petroleum.

D. 17.28 Fractional distillation : A process of refining of petroleum based on the difference in the boiling points of the products.

D. 17.29 Cracking : Thermal decomposition of larger, less volatile hydrocarbons into smaller, more volatile hydrocarbons.

Q. 17.1 (i) What is organic chemistry?
(ii) Why are the compounds of carbon studied as a separate branch of chemistry?

Answer : (i) Organic chemistry is the name given to the study of the chemistry of carbon compounds.

(ii) Since the number of carbon compounds is extremely large and the properties of these compounds are very different from inorganic compounds, they are studied as a separate branch of chemistry.

Q. 17.2 What are the differences in the properties of organic and inorganic compounds?

Answer : See Table 17.1

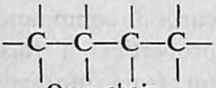
TABLE 17.1 DIFFERENCES BETWEEN ORGANIC AND INORGANIC COMPOUNDS

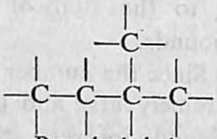
S. no.	*Property*	*Organic*	*Inorganic*
1.	Solubility in water and organic solvents	Generally insoluble in water, but soluble in organic solvents	Generally soluble in water but insoluble in organic solvents
2.	Melting and boiling points	Generally low (hence they are volatile in nature)	Generally high
3.	Combustibility	Inflammable	Generally non-inflammable.
4.	Molecular weights	Several compounds have very high molecular weights (e.g. glucose, $C_6H_{12}O_{16}$)	Generally low
5.	Homologous series	Can be grouped into families (homologous series) having general formula, common methods of preparation and similar properties	Cannot be grouped into such series
6.	Isomerism	Many compounds exhibit isomerism	Very few compounds exhibit isomerism
7.	Thermal stability	Usually decompose on heating	Do not generally decompose on heating
8.	Bonding	Generally covalent	Mostly ionic
9.	Conductivity	Generally non-conducting	Generally conducting in molten state or aqueous solutions

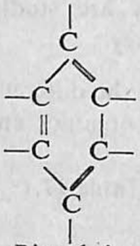
Q. 17.3 (i) Why does carbon form such a large number of compounds?

(ii) What is isomerism?

Answer : (i) Amongst all the elements carbon forms the largest number of compounds. This is possible because carbon can combine covalently with other carbon atoms almost endlessly and in a number of ways, viz. open chain, branched chain and ring chain. This property is known as *catenation*.

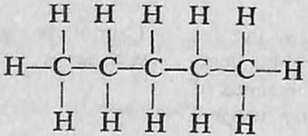

Open chain

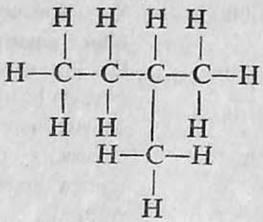

Branched chain

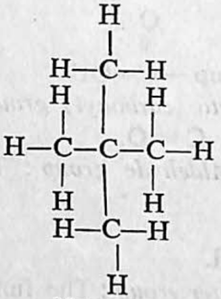

Ring chain

Thus, a large number of carbon compounds containing chains of linked carbon atoms can be formed.

(ii) *Isomerism* is defined as the property by virtue of which two or more compounds can possess the same molecular formula but different properties, on account of differences in their structures. Thus the formula C_5H_{12} represents three different compounds


Pentane

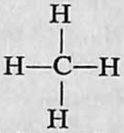

Isopentane

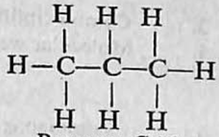

Neopentane

Q. 17.4 What is the general name given to all compounds containing carbon and hydrogen only? Discuss the different types of such compounds, giving specific examples.

Answer : Compounds containing only carbon and hydrogen are known as *hydrocarbons*. They do not contain atoms of other elements like oxygen, nitrogen, chlorine, bromine, etc., which may be present in other types of organic compounds. Hydrocarbons are generally of three types.

(a) *Saturated hydrocarbons* : Hydrocarbons in which all the four valencies of a carbon atom are satisfied by single covalent bonds are called saturated hydrocarbons or *alkanes*. For example,

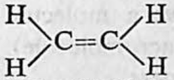

Methane, CH_4


Propane, C_3H_8

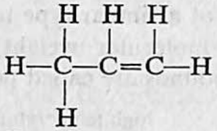
The general formula of alkanes is C_nH_{2n+2}.

(b) *Unsaturated hydrocarbons* : These are hydrocarbons containing at least one pair of carbon atoms joined by a double or a triple covalent bond. The unsaturated hydrocarbon with a double bond is called an *alkene* (general formula C_nC_{2n}). The unsaturated hydrocarbon with a triple bond is known as an *alkyne* (general formula C_nH_{2n}).

Alkenes



Ethylene or ethene,
C_2H_4 (n=2)



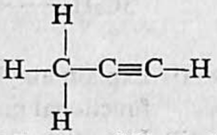
$H-\overset{H}{\underset{H}{C}}-\overset{H}{C}=\overset{H}{C}-H$

Propylene or propene,
C_3H_6 (n=3)

Alkynes

$H-C\equiv C-H$

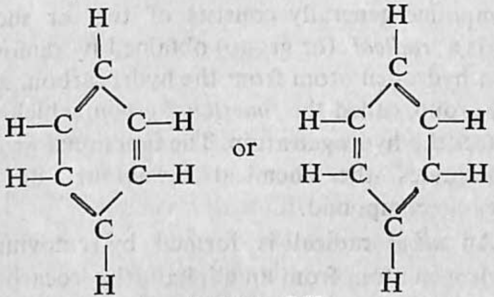
Ethyne, C_2H_2 (n=2)



$H-\overset{H}{\underset{H}{C}}-C\equiv C-H$

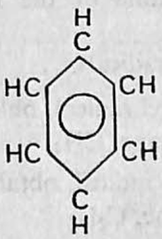
Propyne, C_3H_4 (n=3)

(c) *Aromatic hydrocarbons* : These contain closed chains of carbon atoms. The parent aromatic hydrocarbon is benzene (C_6H_6) which has a ring structure, as shown below.



Benzene, C_6H_6

Both the above structures of benzene are combined in one structure given below.



All other aromatic hydrocarbons are derived from benzene, i.e. they all contain at least one benzene ring.

Q. 17.5 Why is an unsaturated hydrocarbon more reactive than a saturated one?

Answer : An unsaturated hydrocarbon contains a double or triple bond between two carbon atoms. It is more reactive because of the tendency of these carbon atoms to become saturated (i.e. to form single bonds).

Q. 17.6 Explain what is meant by (i) aliphatic hydrocarbons (ii) alicyclic hydrocarbons.

Answer: (i) Aliphatic hydrocarbons are those having open chains. Thus alkanes, alkenes and alkynes are all aliphatic hydrocarbons. Examples: methane, CH_4; ethane, C_2H_6; ethene C_2H_4; ethyne C_2H_2.

(ii) Alicyclic hydrocarbons have a ring structure but resemble aliphatic hydrocarbons in their properties. Examples: cycloalkanes, cycloalkenes and cycloalkynes.

Q. 17.7 What are the important physical properties of hydrocarbons.

Answer: (i) The first few members (C_1 to C_4) of alkanes, alkenes and alkynes are colourless gases. The next 13 or 14 are liquids and the higher hydrocarbons are solids.

(ii) Hydrocarbons are generally soluble in organic solvents such as benzene, chloroform, ether, etc. but almost insoluble in water.

(iii) The density, melting point and boiling point in each series increase with increase in molecular weight.

Q. 17.8 Give the important chemical properties of hydrocarbons.

Answer: The important chemical properties of hydrocarbons are combustion, chlorination, hydrogenation and polymerization.

(i) *Combustion*: Hydrocarbons burn in excess of air to form carbon dioxide and water. Combustion is accompanied by evolution of heat.

The alkanes burn with a non-luminous flame.

$$\underset{\text{methane}}{CH_4}+2O_2 \rightarrow CO_2+2H_2O$$

Alkenes, alkynes and aromatic compounds burn with a smoky luminous flame.

$$\underset{\text{ethene}}{C_2H_4}+3O_2 \rightarrow 2CO_2+2H_2O$$

$$\underset{\text{ethyne}}{2C_2H_2}+5O_2 \rightarrow 4CO_2+2H_2O$$

$$\underset{\text{benzene}}{2C_6H_6}+15O_2 \rightarrow 12CO_2+6H_2O$$

(ii) *Chlorination:* Saturated hydrocarbons (e.g. methane) get chlorinated in the presence of light or at high temperature. In methane, the four hydrogen atoms are successively substituted by chlorine atoms (substitution reaction).

$$CH_4+Cl_2 \rightarrow \underset{\text{methyl chloride}}{CH_3Cl}+HCl$$

$$CH_3Cl+Cl_2 \rightarrow \underset{\text{methylene chloride}}{CH_2Cl_2}+HCl$$

$$CH_2Cl_2+Cl_2 \rightarrow \underset{\text{chloroform}}{CHCl_3}+HCl$$

$$CHCl_3+Cl_2 \rightarrow \underset{\text{carbon tetrachloride}}{CCl_4}+HCl$$

The reactions between unsaturated hydrocarbons and chlorine are addition reactions, forming di- and tetrachloroalkanes.

$$\underset{\text{ethene}}{C_2H_4}+Cl_2 \rightarrow \underset{\text{dichloroethane}}{C_2H_4Cl_2}$$

$$\underset{\text{ethyne}}{C_2H_2}+2Cl_2 \rightarrow \underset{\text{tetrachloroethane}}{C_2H_2Cl_4}$$

Benzene shows both addition and substitution reactions with chlorine.

$$C_6H_6+Cl_2 \xrightarrow[\text{Fe or I}]{\text{catalyst}} \underset{\text{chlorobenzene}}{C_6H_5Cl}+HCl \text{ (substitution)}$$

$$C_6H_6+3Cl_2 \xrightarrow{\text{light}} \underset{\text{benzene hexachloride}}{C_6H_6Cl_6} \text{ (addition)}$$

(iii) *Hydrogenation:* Saturated hydrocarbons are not hydrogenated further. Unsaturated hydrocarbons are transformed into saturated ones by catalytic hydrogenation.

$$C_2H_4+H_2 \xrightarrow{\text{Ni, heat}} C_2H_6$$

$$C_2H_2+2H_2 \xrightarrow{\text{Ni, heat}} C_2H_6$$

Aromatic hydrocarbons give cyclic saturated hydrocarbons. Benzene, in the presence of nickel at 200°C forms cyclohexane.

$$C_6H_6+3H_2 \xrightarrow{\text{Ni, heat}} C_6H_{12}$$

(iv) *Polymerization*: This is also an addition reaction shown by unsaturated hydrocarbons. It is the joining up of a large number of molecules of a similar type to give a molecule with high molecular weight (macromolecule). Such compounds are called polymers.

$$n\ C_2H_4 \xrightarrow[\text{and pressure}]{\text{high temperature}} \underset{\text{polyethylene}}{(-CH_2-CH_2-)_n}$$

$$3C_2H_2 \xrightarrow{873\text{ K}} \underset{\text{benzene}}{C_6H_6}$$

Q. 17.9 (i) Explain alkyl and aryl radical, and functional groups.

(ii) List the common radicals and functional groups.

Answer: (i) A hydrogen atom of a hydrocarbon can be replaced by another atom or group to form a new compound. Thus an organic compound generally consists of two or more parts,a *radical* (or group) obtained by removal of a hydrogen atom from the hydrocarbon, and the group, called the *functional group*, which replaces the hydrogen atom. The functional group determines the chemical behaviour of an organic compound.

An *alkyl* radical is formed by removing a hydrogen atom from an aliphatic hydrocarbon.

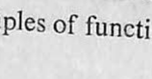
An *aryl* radical is formed by removing a hydrogen atom from an aromatic hydrocarbon. A radical is named by replacing the '-ane', '-ene' or '-yne' in the name of the hydrocarbon by '-yl'.

(ii) Examples of radicals:

CH_3—methyl radical, obtained from methane, CH_4

C_2H_5—ethyl radical, obtained from ethane, C_2H_6

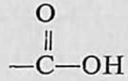
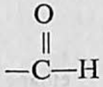
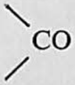
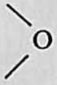
$CH_3-CH_2-CH_2-$*n*-propyl radical, obtained from propane, C_3H_8



$(CH_3)_2CH-$isopropyl radical, obtained from propane, C_3H_8)

C_6H_5—phenyl radical, obtained from benzene, C_6H_6

Examples of functional groups:

—Cl, —Br, —I	halogen groups
 $-\overset{\overset{O}{\Vert}}{C}-OH$	carboxy (carboxylic) group
—OH	hydroxy (alcoholic) group
 $-\overset{\overset{O}{\Vert}}{C}-H$	aldehyde group
	ketonic (carbonyl) group
$-NH_2$	amino group
—COOR	ester group
$-NO_2$	nitro group
	ether

Q. 17.10 What is a homologous series? What are the characteristics of a homologous series? Give examples.

Answer: A series containing organic compounds of same class having similar chemical properties but with different molecular formulae, is called a homologous series.

A homologous series has the following characteristics.

(i) All members of a homologous series can be assigned a general formula.
Examples:

C_nH_{2n+2}	alkanes
C_nH_{2n}	alkenes
C_nH_{2n-2}	alkynes
$C_nH_{2n+1}OH$	alcohols
$C_nH_{2n}O_2$	carboxylic acids

(ii) Each member of a series differs from its immediate neighbour by CH_2.
Examples: In alkanes (C_nH_{2n+2}) the compounds are CH_4, C_2H_6, C_3H_8, C_4H_{10}, etc. All of these differ from their nearest neighbours by CH_2.

(iii) All members of a homologous series have the same functional group.

(iv) Members of a series can all be prepared by a general method of preparation.

(v) The physical properties of a series show a regular change with rise in molecular weight.

(vi) The chemical properties of a series are similar. This is because all members of a series have the same functional group.

Q. 17.11 What are the two methods used for naming organic compounds? What is the principle of the IUPAC system?

Answer: The two methods used for naming organic compounds are:

(i) Commonly used names.

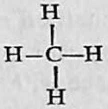
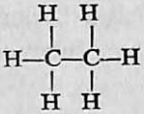
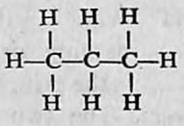
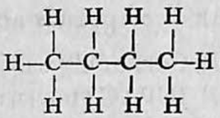
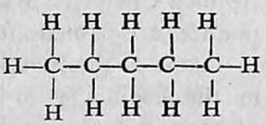
(ii) IUPAC (International Union of Pure and Applied Chemists) system. In this system compounds are named after the parent alkane with the name of the functional group being added in the beginning or at the end of the alkane name.

Q. 17.12 How are the following groups of compounds named in the IUPAC system? Give their general formula, and the formula, structure, common names (where applicable) and IUPAC names of the first three members (give the first five in case of alkanes).

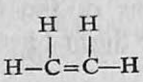
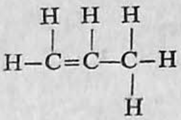
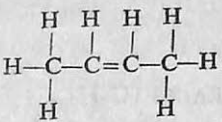
(i) alkanes
(ii) alkenes
(iii) alkynes
(iv) alkyl chlorides
(v) alcohols
(vi) carboxylic acids
(vii) aldehydes
(viii) ketones

Answer

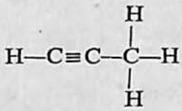
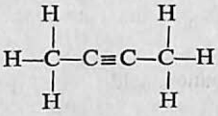
(i) ALKANES (C_nH_{2n+2}) The prefixes meth-, eth-, prop-, but-, pent-, hex-, hept-, oct- etc. are used for compounds containing 1, 2, 3, 4, 5, 6, 7, 8, etc. carbon atoms respectively. In alkanes the common suffix '-ane' is used.

Formula	Structure	Common name	IUPAC name
1. CH_4	 $H-\overset{H}{\underset{H}{C}}-H$	methane	methane
2. C_2H_6	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$	ethane	ethane
3. C_3H_8	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$	propane	propane
4. C_4H_{10}	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ (one more isomer possible)	*n*-butane	butane
5. C_5H_{12}	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$ (two more isomers possible)	*n*-pentane	pentane

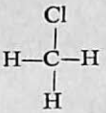
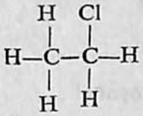
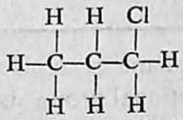
(ii) ALKENES (C_nH_{2n})*:* The names are derived from the corresponding alkane. The suffix '-ane' is changed to '-ene'.

Formula	Structure	Common name	IUPAC name	Parent alkane
1. C_2H_4	 $H-\overset{H}{C}=\overset{H}{C}-H$	ethylene	ethene	ethane
2. C_3H_6	 $H-\overset{H}{C}=\overset{H}{C}-\overset{H}{\underset{H}{C}}-H$	propylene	propene	propane
3. C_4H_8	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{C}=\overset{H}{C}-\overset{H}{\underset{H}{C}}-H$ (one more isomer possible)	butylene	butene-2	butane

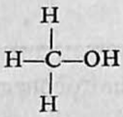
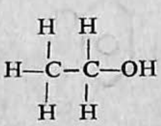
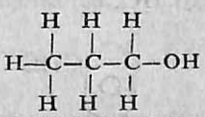
(iii) ALKYNES (C_nH_{2n-2}): The names are derived from the corresponding alkane. The suffix '-ane' is replaced by '-yne'. Note that alkyne corresponding to methane is not possible.

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
1. C_2H_2	$H-C\equiv C-H$	acetylene	ethyne	ethane
2. C_3H_4	 $H-C\equiv C-\overset{H}{\underset{H}{C}}-H$	methyl acetylene or allylene	propyne	propane
3. C_4H_6	 $H-\overset{H}{\underset{H}{C}}-C\equiv C-\overset{H}{\underset{H}{C}}-H$ (one more isomer possible)	dimethyl acetylene	butyne-2	butane

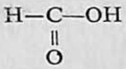
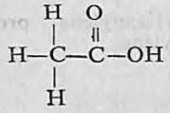
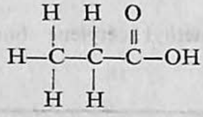
(iv) ALKYL CHLORIDES ($C_nH_{2n+1}Cl$): 'Chloro-' is added before the name of the parent alkane.

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
1. CH_3Cl	 $H-\overset{Cl}{\underset{H}{C}}-H$	methyl chloride	chloromethane	methane
2. C_2H_5Cl	 $H-\overset{H}{\underset{H}{C}}-\overset{Cl}{\underset{H}{C}}-H$	ethyl chloride	chloroethane	ethane
3. C_3H_7Cl	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{Cl}{\underset{H}{C}}-H$ (one more isomer possible)	propyl chloride	1-chloropropane	propane

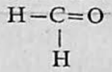
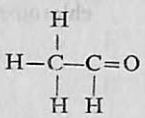
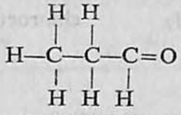
(v) ALCOHOLS ($C_nH_{2n+1}OH$): The last letter 'e' of the parent alkane is replaced by '-ol'.

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
1. CH_3OH	 $H-\overset{H}{\underset{H}{C}}-OH$	methyl alcohol	methanol	methane
2. C_2H_5OH	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$	ethyl alcohol	ethanol	ethane
3. C_3H_7OH	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$ (one more isomer possible)	propyl alcohol	propanol-1	propane

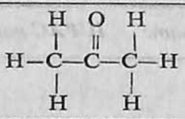
(vi) Carboxylic Acids ($C_nH_{2n}O_2$)

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
1. $HCOOH$	 $H-\underset{\underset{O}{\|}}{C}-OH$	formic acid	methanoic acid	methane
2. CH_3COOH	 $H-\overset{H}{\underset{H}{C}}-\overset{\overset{O}{\|}}{C}-OH$	acetic acid	enthanoic acid	ethane
3. C_2H_5COOH	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{\overset{O}{\|}}{C}-OH$	methyl acetic acid	propanoic acid	propane

(vii) Aldehydes ($C_nH_{2n}O$): The last letter 'e' of the parent alkane is replaced by '–al'.

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
1. $HCHO$	 $H-\underset{H}{C}=O$	formaldehyde	methanal	methane
2. CH_3CHO	 $H-\overset{H}{\underset{H}{C}}-\underset{H}{C}=O$	acetaldehyde	ethanal	ethane
3. C_2H_5CHO	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\underset{H}{C}=O$	propionaldehyde	propanal	propane

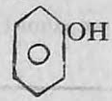
(viii) Ketones ($C_nH_{2n}O$): The last letter 'e' of the parent alkane is replaced by '-one'. (The general formula is the same as that of aldehydes but the functional group is different.) Ketones corresponding to methane and ethane are not known.

Formula	*Structure*	*Common name*	*IUPAC name*	*Parent alkane*
C_2H_6CO $(CH_3 \cdot CO \cdot CH_3)$	 $H-\overset{H}{\underset{H}{C}}-\overset{\overset{O}{\|}}{C}-\overset{H}{\underset{H}{C}}-H$	Acetone	Propanone	Propane

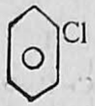
Q. 17.13 Give the names and structures of the following benzene derivatives.
(a) C_6H_5OH (b) C_6H_5Cl (c) C_6H_5CHO (d) C_6H_5COOH (e) $C_6H_5CH_3$ (f) $C_6H_5NH_2$

Answer

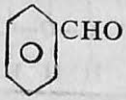
(a) C_6H_5OH, phenol



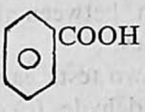
(b) C_6H_5Cl, chlorobenzene



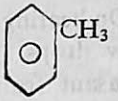
(c) C_6H_5CHO, benzaldehyde



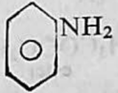
(d) C_6H_5COOH, benzoic acid



(e) $C_6H_5CH_3$, methyl benzene (toluene)

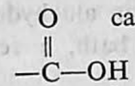
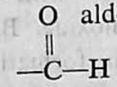


(f) $C_6H_5NH_2$, aminobenzene (aniline)



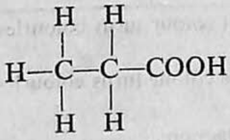
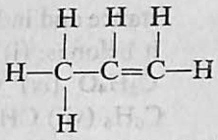
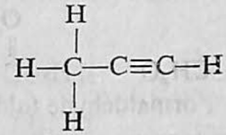
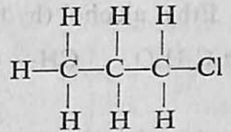
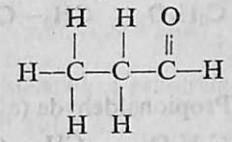
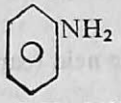
Q. 17.14 Write the functional groups present in the following compounds: CH_3COOH, C_2H_5OH, C_2H_5Cl, $C_2H_5COOCH_3$, CH_3CHO, CH_3COCH_3, CH_3NH_2.

Answer

Compound	*Functional group*
(1) CH_3COOH	 $-\overset{O}{\overset{\|}{C}}-OH$ carboxylic
(2) C_2H_5OH	$-OH$, hydroxy
(3) C_2H_5Cl	$-Cl$, chlorine
(4) $C_2H_5COOCH_3$	$-COOCH_3$, ester
(5) CH_3CHO	 $-\overset{O}{\overset{\|}{C}}-H$ aldehyde
(6) CH_3COCH_3	$>C{=}O$, carbonyl (represents ketone)
(7) CH_3NH_2	$-NH_2$, amino

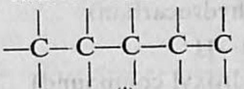
Q. 17.15 Write the structures of the following compounds:
(1) propanoic acid (2) propene
(3) propyne (4) chloropropane
(5) propanal (6) aminobenzene

Answer

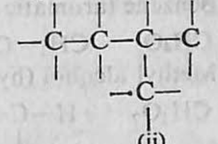
Compound	*Structure*
1. Propanoic acid	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-COOH$ or CH_3-CH_2-COOH
2. Propene	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{C}=\overset{H}{C}-H$ or $CH_3-CH=CH_2$
3. Propyne	 $H-\overset{H}{\underset{H}{C}}-C\equiv C-H$ or $CH_3-C\equiv CH$
4. Chloropropane	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-Cl$ or $CH_3-CH_2-CH_2Cl$
5. Propanal	 $H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{O}{\overset{\|}{C}}-H$ or CH_3-CH_2-CHO
6. Aminobenzene	 or $C_6H_5\cdot NH_2$

Q. 17.16 Give the possible arrangements for a compound containing five carbon atoms bonded to one another by single bonds.

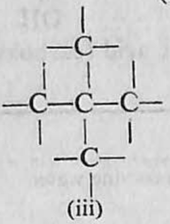
Answer: There are three possible arrangements.



(i)



(ii)

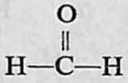


(iii)

Q. 17.17 Write the structural formula for one substance with each of the following molecular formulae. Name the substance and indicate the class to which it belongs: (i) CH_2O (ii) C_2H_6O (iii) C_2H_4O (iv) C_3H_6O (v) $C_2H_4O_2$ (vi) C_6H_6 (vii) CH_4O (viii) CH_2O_2.

Answer

(a) CH_2O



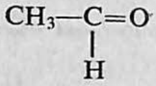
$H-\overset{\overset{\displaystyle O}{\|}}{C}-H$

Formaldehyde (aldehydic compound)

(b) C_2H_6O CH_3-CH_2-O-H

Ethyl alcohol (hydroxyl compound)

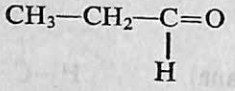
(c) C_2H_4O



$CH_3-\underset{\underset{\displaystyle H}{|}}{C}=O$

Acetaldehyde (aldehydic compound)

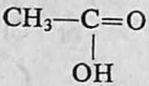
(d) C_3H_6O



$CH_3-CH_2-\underset{\underset{\displaystyle H}{|}}{C}=O$

Propionaldehyde (aldehydic compound)

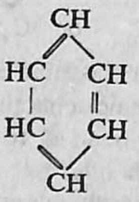
(e) $C_2H_4O_2$



$CH_3-\underset{\underset{\displaystyle OH}{|}}{C}=O$

Acetic acid (carboxylic compound)

(f) C_6H_6

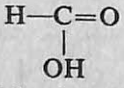


Benzene (aromatic hydrocarbon)

(g) CH_4O CH_3-O-H

Methyl alcohol (hydroxyl compound)

(h) CH_2O_2



$H-\underset{\underset{\displaystyle OH}{|}}{C}=O$

Formic acid (carboxylic compound)

Q. 17.18 (i) What tests will you perform to distinguish between alkanes, alkenes and alkynes.

(ii) Give two tests each for (a) alcohols (b) aldehydes (c) carboxylic acids.

Answer: (i) See Table 17.2.

(ii) (a) *Alcohols*: 1. On heating an alcohol with acetic acid and a few drops of concentrated sulphuric acid, a pleasant fruity smell (of an ester) is given out.

$$CH_3CH_2OH+CH_3COOH \xrightarrow[\text{heat}]{\text{conc. } H_2SO_4} \underset{\text{ester}}{CH_3COOC_2H_5}+H_2O$$

2. On adding a few drops of ceric ammonium nitrate to an alcohol, the solution becomes deep red.

(b) *Aldehydes*: 1. On shaking an aldehyde with a few drops of Schiff's reagent, a pink colour is obtained.

2. On adding a few drops of Fehling's solution to an aldehyde and heating the mixture in a water bath, a reddish brown precipitate is formed.

(c) *Carboxylic acids*: 1. An aqueous solution of a carboxylic acid will turn blue litmus red. It will react with sodium bicarbonate to give carbon dioxide. Brisk effervescence is observed due to the formation of CO_2.

2. On heating a carboxylic acid with ethyl alcohol and a few drops of concentrated sulphuric acid, a pleasant fruity smell (of an ester) is given out.

Q. 17.19 What is petroleum? How is it formed? What is its composition? From where does it derive its name?

Answer: Petroleum (also known as crude

TABLE 17.2 TESTS FOR ALKANES, ALKENES AND ALKYNES

Test	*Alkane*	*Alkene*	*Alkyne*
1. Action of bromine water	No reaction	Brown colour turns colourless	Brown colour turns colourless
2. Baeyer's test (action of aq. soln. of $KMnO_4$)	No reaction	Purple colour turns colourless	Purple colour turns colourless
3. Action of ammoniacal $AgNO_3$	No reaction	No reaction	White ppt.

oil) is a black viscous liquid. It occurs under the earth's crust entrapped in rocks. It is formed by bacterial decomposition of the remains of plants and animals at high temperature and pressure under the earth's crust. It consists of a mixture of a number of hydrocarbons. It derives its name from the Latin words *petra* (meaning rock) and *oleum* (meaning oil).

Q. 17.20 (i) What do you understand by refining of petroleum? How are the various products of refining separated?

(ii) List the different fractions obtained from the refining of petroleum and mention their composition, boiling range and uses.

Answer : (i) Refining of petroleum is the process by which various useful products are separated from the crude oil. These products are obtained by a process known as *fractional distillation*, which is a method of separation based on the difference in the boiling points of the products.

The vapours of the crude oil are made to rise in a fractionating tower. The vapours of higher boiling point (i.e. less volatile) liquids condense in the lower part while the more volatile liquids condense in the higher parts. Trays are fitted at different heights to collect various products (Fig. 17.1). The products obtained can be further fractionally distilled.

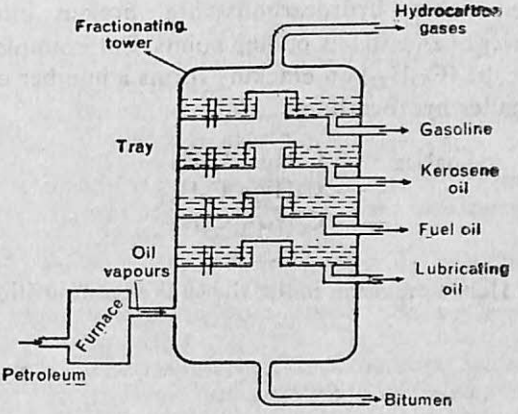


FIG. 17.1 Fractional distillation of petroleum.

(ii) The list is given in Table 17.3.

Q. 17.21 What is meant by cracking? What types of hydrocarbons are formed during cracking? How can we improve the fuel value of low grade fuels?

Answer : Kerosene and gas oils are known to consists of hydrocarbons of high molecular weights and high boiling points. They are, therefore, fuels of low grading. They can be converted into good fuels by *cracking*, which consists of

TABLE 17.3

	Fraction	*Composition*	*Boiling point range*	*Uses*
1.	Gas hydrocarbons	C_1-C_4 alkanes	Below 30° C	As fuel and for making carbon black
2.	Petroleum ether	C_5-C_7 alkanes	30-60°C	As solvent and in drycleaning
3.	Petrol or gasoline	C_6-C_{12} alkanes	50-200°C	As motor fuel
4.	Kerosene oil	C_{12}-C_{15} alkanes	200-300°C	As fuel
5.	Fuel oil	C_{15}-C_{18} alkanes	250-350°C	As fuel in diesel engines
6.	Lubricating oil	C_{20} and higher alkanes	350-400°C	As lubricants and in cosmetic creams
7.	Bitumen	Higher hydrocarbons	Above 400°C	For roads and in lubricants

heating these at high temperature either under high pressure (thermal cracking) or in the presence of a catalyst (catalytic cracking) when the higher hydrocarbons are broken into lower ones with low boiling points. For example, decane ($C_{10}H_{22}$) on cracking forms a number of smaller hydrocarbons.

$$\begin{aligned} C_{10}H_{22} &\longrightarrow C_8H_{18}+C_2H_4 \\ &\longrightarrow C_4H_{10}+C_6H_{12} \\ &\longrightarrow C_6H_{14}+C_4H_8 \\ &\quad \text{etc.} \end{aligned}$$

Hence cracking is the thermal decomposition of larger hydrocarbons into smaller molecules. During cracking more volatile, lower hydrocarbons are formed.

Q. 17.22 (i) What is synthetic petrol?
(ii) What are petrochemicals?

Answer : (i) Synthetic petrol is the synthesised mixture of hydrocarbons which resembles petrol in its properties.

(ii) Petrochemicals are substances such as nylon, detergents, insecticides, etc. which are made from chemicals such as hydrocarbons obtained from petroleum.

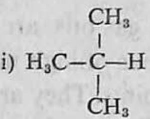
EXERCISES

17.1 Classify the following hydrocarbons into saturated, unsaturated and aromatic types : (i) ethane, C_2H_6 (ii) butylene, C_4H_8 (iii) butane, C_4H_{10} (iv) butyne, C_4H_6 (v) benzene, C_6H_6.

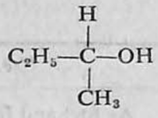
17.2 Classify each of the following molecules as belonging to an alkane, alkene or an alkyne :

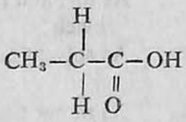
(i) $CH_3CH_2\ CH = CH_2$

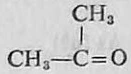
(ii) $CH_3\ C \equiv CH$

(iii) 
$H_3C-\overset{CH_3}{\underset{CH_3}{C}}-H$

17.3 Classify the following compounds as an alcohol, an ether, an aldehyde, a ketone or an acid.

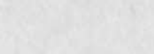
(a) 
$C_2H_5-\overset{H}{\underset{CH_3}{C}}-OH$

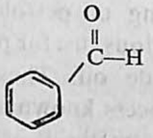
(b) 
$CH_3-\overset{H}{\underset{H}{C}}-\underset{\overset{\|}{O}}{C}-OH$

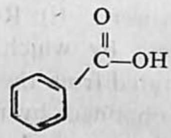
(c) 
$CH_3-\overset{CH_3}{C}=O$

(d) $CH_3-CH_2-O-CH_2-CH_3$

17.4 Classify the following compounds according to the kind of functional group present.

(a) 
$CH_3-\overset{O}{\overset{\|}{C}}-CH_3$
(b) $CH_3\cdot CH_2O\cdot CH_3$

(c) 

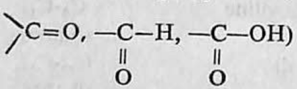
(d) 

(f) $CH_3\cdot CH_2\cdot CH_2\cdot CH_2\cdot OH$

17.5 An organic compound has the formula R—X. The part R is called the alkyl group. What is the name given to the part X?

17.6 What is polymerisation? What are its industrial uses?

17.7 Match the entries in column A with those in column B.

1. A saturated hydrocarbon contains (double bond, single bond, triple bond).
2. Compounds having the same molecular formula but different structural formulae are known as (isotopes, isomers, allotropes).
3. The compound with structural formula $CH_3—C{=}CH$ is known as (propene, propyne, propane).
4. The general formula for alkenes is (C_nH_{2n}, C_nH_{2n-2}, C_nH_{2n+2}).
5. The functional group in an alcohol is (—OH,  $>C=O$, $-\underset{\overset{\|}{O}}{C}-H$, $-\underset{\overset{\|}{O}}{C}-OH$)
6. The molecular formula C_3H_8O represents (an aldehyde, a ketone, an alcohol, an ester).
7. In a homologous series each member differs from its immediate neighbour by a ($—CH_3$, $—C_2H_5$, $>CH_2$) group.

8. Oxidation of an aldehyde will produce (ketone, acid, amine).

17.8 Draw a line under the most appropriate answer.

COLUMN A

1. Properties of organic compounds are entirely
2. Isomerism is the phenomenon where a single molecular formula can represent
3. Compounds having multiple bonds
4. Organic compounds are generally
5. Hydrocarbons in which all the four valencies of a carbon atom are satisfied by
6. A homologous series contains organic compounds
7. Petroleum is a crude oil
8. Cracking is the thermal decomposition
9. The fuel value of a low grade fuel
10. Synthetic petrol is the synthesised mixture of

COLUMN B

1. hydrocarbons which resembles petrol.
2. of larger hydrocarbons into smaller molecules in the presence of a catalyst.
3. can be improved by cracking.
4. two or more than two structural formulae.
5. different from the properties of inorganic compounds.
6. are unsaturated hydrocarbons.
7. soluble in organic solvents.
8. single covalent bonds are called saturated hydrocarbons.
9. of the same class having similar chemical properties but with different molecular formulae.
10. which occurs under the earth's crust entrapped in rocks.

17.9 Define and give examples in each of the following cases : (i) ketone (ii) ether (iii) carboxylic acid (iv) aldehyde.

17.10 What is the difference between the structures of saturated and unsaturated hydrocarbons?

17.11 How does an alcohol differ from an inorganic hydroxide?

17.12 What reaction, other than oxidation, is characteristic of the saturated hydrocarbons? Give examples.

17.13 How would you test for the presence of an (i) alcohol (ii) acid (iii) ketone (iv) aldehyde.

17.14 What do you understand by the term homologous series? Illustrate your answer with suitable examples.

17.15 What is a functional group? What is its importance?

17.16 Define cracking. Describe its significance in the petroleum industry.

Questions from Examination Papers

ALL INDIA SECONDARY BOARD

(*Note* : References to unit number and volume are given in brackets.)

1979

1. (i) 1·5 g of metallic sodium reacts with excess of water. What is the volume of hydrogen evolved at STP? (Atomic masses in amu are Na = 23, H = 1, O = 16.) *(3, Vol 1)*

(ii) Write the electronic configuration of an element X, whose atomic number is 12. *(5, Vol 1)*

(iii) In the formation of the compound AB, atoms of A lost one electron each, while atoms of B gained one electron each. Predict the *two* properties of AB. *(6, Vol 1)*

(iv) A sample of pond water contains Ca^{2+} ions. Give the chemical equation of the reaction involved in the method you would use for softening such water. *(12, Vol 2)*

(v) How much urea should be added to 200 ml of water to get a 0·1 Molar solution? *(13, Vol 2)*
(Molecular weight of urea = 60)

(vi) Write the names of any *two* isomers represented by the molecular formula C_5H_{12}. *(12, Vol 2)*

(vii) A sodium salt, when treated with dilute sulphuric acid gave out a gas, which had pungent smell and was acidic in nature. The gas bleached litmus solution. What was the salt? *(15, Vol 2)*

2. (a) Fill in the following blanks. *(5, Vol 1)*

Mass Number	Atomic Number	Number of Protons	Number of Neutrons	Valency	Symbol
14	7	....	....	....	....

(b) For each of the following triads, name the element with the characteristic specified below. *(7, Vol 1)*

	Least atomic diameter	Chemically least active
(i) F, Cl, Br	....	....
(ii) Li, Na, K	....	....

(c) Give two chemical reactions to show that oxygen and sulphur behave in the same manner. *(9, Vol 1)*

3. (a) (i) When magnesium burns in chlorine, it forms $MgCl_2$. On the basis of electron-transfer process, state which element is oxidised and which is reduced? *(14, Vol 2)*

(ii) The following is the equation of a reaction:

$$H_2S+I_2 \longrightarrow 2HI+S$$

Select the oxidising agent and the reducing agent in the reaction. *(14, Vol 2)*

(b) An oxide ore has been found to contain some impurities, which are magnetic. List the various steps you would use for getting pure metal from the ore. *(11, Vol 2)*

(c) An aluminium spoon is to be electroplated with nickel. Draw a labelled sketch of the apparatus used for the purpose. Give the reaction taking place at cathode. *(13, Vol 2)*

4. (a) (i) What property of carbon is responsible for its forming the largest number of compounds? *(17, Vol 2)*

(ii) Give *one* point of difference between two allotropes of carbon, which is based on their difference in structures. *(15, Vol 2)*

(b) An organic compound has the molecular formula $C_2H_4O_2$ and is acidic in nature. On heating with ethyl alcohol and conc. sulphuric acid, vapours with pleasant fruity smell are given out. What is the compound A and what is the chemical equation involved in the reaction? *(17, Vol 2)*

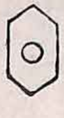
(c) Complete *one* of the following sets of equations.

(i) $C_2H_5Cl+Na \longrightarrow$

(ii) $CH_3CH_2OH \xrightarrow{\text{Oxidation}}$

Or

(i) $CH{\equiv}CH+Br_2 \longrightarrow$

(ii)  $+H_2 \longrightarrow$ *(17, Vol 2)*

5. (a) Draw a graph to show the variation of volume V of a given quantity of a gas with pressure P at constant temperature based on the undermentioned data. *(4, Vol 1)*

Temperature 300°K

Pressure/atmospheres	1	2	3	4	5
Volume/litres	2	1	0·66	0·5	0·4

(b) State any *two* conditions required for the process of combustion to take place. Give *one* example of each of the following:

(i) a gas used for industrial purpose.

(ii) a liquid propellant. *(16, Vol 2)*

6. (a) How is hydrogen chloride gas prepared in the laboratory? Give only the chemical equation of the reaction involved in the preparation and a labelled sketch of the apparatus used for the purpose. *(8, Vol 1)*

(b) What happens when:

(i) ammonium hydroxide is added to a solution of aluminium sulphate? *(10, Vol 1)*

(ii) hydrogen sulphide is passed through a solution of lead nitrate? Give the chemical equations of the reactions involved. *(9, Vol 1)*

Or: How is hydrogen sulphide prepared in the laboratory? Give only the labelled sketch of the apparatus used in the preparation and the chemical equation of the reaction involved. *(9, Vol 1)*

1980

1. (i) If an element M has atomic weight 24 and atomic number 12, how many neutrons does its atom contain? How many electrons will be present in K, L and M energy shells of its atom? *(5, Vol 1)*

(ii) 10 moles of oxygen are confined in a vessel with a capacity of 221 litres. If the temperature is 0°C what is the pressure? *(4, Vol 1)*

(iii) How many moles of oxygen can be obtained by the decomposition of 1 mole of potassium chlorate in the following reaction?

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

How many moles of the reactant are needed for obtaining 1 mole of oxygen? *(3, Vol 1)*

(iv) A gas occupies a certain volume at 600 mm pressure and 27°C. If the pressure is reduced to 500 mm, what should be the temperature to keep the volume constant? *(4, Vol 1)*

(v) Compare an electron, a proton and a neutron in respect of their relative masses and charges. *(5, Vol 1)*

(vi) Ethane burns in oxygen to form carbon dioxide and water. Write a balanced chemical equation for the reaction.

From the equation find the weight of oxygen required for burning 15 g of ethane. *(3, Vol 1)*

(vii) What temperature would be necessary to double the volume of a gas initially at STP if the pressure is decreased by 25%? *(4, Vol 1)*

2. (a) In the formation of a compound AB, atoms of element A lost two electrons while atoms of element B gained two electrons each. Predict two properties of AB. Which of the elements A and B is oxidised in the formation of AB. *(6, Vol 1)*

(b) What is a period in a periodic table? How do atomic structures change in a period with increase in atomic numbers from left to right? *(7, Vol 1)*

(c) State one reason for keeping nitrogen and phosphorus in the same group of the periodic table. *(10, Vol 1)*

(d) State the reason for any physical property in which water and hydrogen sulphide differ from each other. *(9, Vol 1)*

3. (a) Mention two properties which generally distinguish metals from non-metals. *(11, Vol 2)*

(b) On the basis of the equation:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) +$ heat energy, suggest whether at equilibrium the extent of formation of ammonia will increase, decrease or remain unchanged when:

(i) pressure is increased?

(ii) temperature is increased? *(14, Vol 2)*

(c) Calculate the molarity of a solution containing 6·84 g of a substance in 250 ml of solution if the molecular weight of the substance is 342. *(13, Vol 2)*

4. (a) State the characteristics of a good fuel. What is 'calorific value of a fuel'? *(16, Vol 2)*

Or: Describe the importance of coke in metallurgical processes. *(15, Vol 2)*

(b) Give two chemical reactions to show that oxygen and sulphur behave in the same manner. *(9, Vol 1)*

5. (a) Two gas jars contain ethane and ethylene separately. Give one chemical test to distinguish one from the other. Give one use of ethylene. *(17, Vol 2)*

(b) Draw a neat labelled diagram of the apparatus used for showing in the laboratory that hydrogen chloride gas is very soluble in water. How would you show that the solution formed is acidic? *(8, Vol 1)*

6. (a) Describe briefly how hydrogen sulphide is prepared in the laboratory from iron sulphide (no diagram is required). What happens when hydrogen sulphide is passed through aqueous solutions of:

(i) copper sulphate, and

(ii) sulphur dioxide? Give equations of reactions. *(9, Vol 1)*

(b) Write the names of elements known as halogens. Give one use each for any two of these elements. *(8, Vol 1)*

(c) Name in each case one compound of nitrogen which is used as:

(i) a fertilizer, and

(ii) a laboratory reagent. *(10, Vol I)*

1981

1. Complete the following statements.

(i) Substances having similar chemical properties, but different physical properties are termed...... *(5, Vol I)*

(ii) If sodium bicarbonate is added to a carboxylic acid solution, vigorous reaction with the evolution of CO_2 occurs. The phenomenon is known as........... *(13, Vol 2)*

(iii) Organic compounds having $-NH_2$ functional group are known as......... *(17, Vol 2)*

(iv) Fuels used in rockets are called...... *(16, Vol 2)*

(v) The electricity during the elecrolysis of a salt solution is carried by......... *(13, Vol 2)*

(vi) Process of giving a fine coating of zinc metal on iron metal is known as......... *(11, Vol 2)*

(vii) The fundamental particle not present in a hydrogen atom is......... *(5, Vol I)*

(viii) In forming N_2 molecule......electrons are shared by each atom of nitrogen. *(6, Vol I)*

(ix) Two atoms of the same element combine to form a molecule. The bond between them is known as...... bond. *(6, Vol I)*

(x) Combination of smaller molecules of a substance to give a higher molecular weight molecule is known as...... *(17, Vol 2)*

2. (a) The valencies or charges on some substances are given below.

Zinc ion.................2+
Nitrogen................3+
Oxygen...................2−
Phosphate ion..........3−
Sodium ion..............1+
Bromide ion............1−
Lead ion................2+

Using the above information write down the chemical formulae of any *two* of the following.

(i) Zinc phosphate

(ii) Nitrogen oxide

(iii) Sodium phosphate

(iv) Lead bromide. *(3, Vol I)*

(b) Suggest a scheme for the separation of constituents of the following mixture:

Sulphur+Sand+Sugar+Iron filings *(2, Vol I)*

Or: Differentiate between:

(i) rapid combustion and spontaneous combustion:

(ii) oxidation and combustion. *(16, Vol 2)*

(c) How much magnesium oxide would be obtained by completely burning 2.4 g of magnesium?
(at. wt. Mg = 24, O = 16) *(3, Vol I)*

(d) A container of 5 litres capacity containing a light gas X at a pressure of 5 atomspheres and temperature 298 K is connected to another empty container of 5 litres capacity at 298 K. What is the final pressure of X in the combined container? *(4, Vol I)*

3. (a) Substances from A to E have in them the distribution of electrons, neutrons and protons as follows.

Substances	Electrons	Neutrons	Protons
A	4	4	3
B	8	9	9
C	18	22	18
D	17	20	17
E	17	18	17

Making use of these data find (i) a cation (ii) an anion (iii) a pair of isotopes (iv) an atom of noble gas. *(5, Vol I)*

(b) A, B and C are three elements which undergo chemical changes according to following equations.

$$A_2O_3+2B \rightarrow B_2O_3+2A$$
$$3CSO_4+2B \rightarrow B_2(SO_4)_3+3C$$
$$3CO+2A \rightarrow A_2O_3+3C$$

Arrange the elements in order of decreasing reactvity. *(14, Vol 2)*

Or: Compare the bleaching action of SO_2 and Cl_2. Give two points of difference only. *(8, 9, Vol I)*

(c) With which industrial preparations are the following processes associated?

(i) Ostwald's process *(10, Vol I)*

(ii) Solvay process *(11, Vol 2)*

(iii) Frasch process *(9, Vol I)*

(iv) Haber's process *(10, Vol I)*

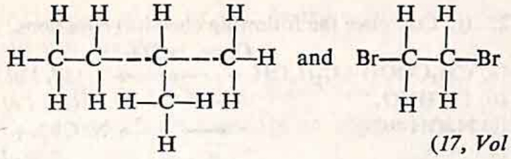
(d) A metal X in the form of turnings reacted with hot concentrated dibasic acid H_2Y and produced deep blue solution of salt XY. When a wire of metal Z was put in the solution of XY the deep blue colour was slowly discharged and colourless ZY salt solution was formed and X was generated. Explain the observations. *(11, Vol 2)*

4. (a) There are three test-tubes A, B and C containing solutions of KI, KBr and KCl separately. How would you find which tube contains which salt? *(8, Vol I)*

(b) Two beakers A and B have 500 ml distilled water in each. In beaker A 100 g of sodium nitrate is dissolved and in B 100 g of urea (NH_2CONH_2) is dissolved. Will the two solutions have equal molarity or not? Explain.
(at. wt. N = 14, Na = 23, O = 16, H = 1, C = 12) *(13, Vol 2)*

Or: A 10^3 M HCl solution has been diluted to 100 times. Calculate the pH of the diluted solution.

(c) Give the IUPAC nomenclature for



(17, Vol 2)

5. (a) Name the metals that can be extracted from the following ores.

(i) Haematite

(ii) Bauxite (11, Vol 2)

(b) Give reasons for any *two* of the following.

(i) In the 'fountain experiment', why does water rush into the flask filled with HCl gas? (8, Vol 1)

(ii) About 80% of N_2 is present in the atmosphere, why does sea water not have it? (10, Vol 1)

Or: Explain any *two* of the following.

(i) Cl_2 gas is passed through cold NaOH solution? (8, Vol 1)

(ii) A stream of CO_2 is passed through lime water? (15, Vol 2)

(iii) SO_2 is passed through saturated solution of H_2S in water? (9, Vol 1)

(c) Explain the principle of carbon tetrachloride fire extinguisher. (16, Vol 2)

1982

1. Complete the following statements.

(i) Before combustion takes place, a substance must be raised to its......temperature. (16, Vol 2)

(ii) When washing soda is dissolved in water the cation produced is......... (13, Vol 2)

(iii) The next higher homologue of ethane is...... (17, Vol 2)

(iv) The law which correlates the variation of volume with temperature at constant pressure is known as...... (4, Vol 1)

(v) An atom of an element has 11 protons, 11 electrons and 12 neutrons. The atomic mass of the atom is...... (5, Vol 1)

(vi) The valency of nitrogen in N_2 molecule is...... (6, Vol 1)

(vii) The element recovered on industrial scale from sea water is...... (8, Vol 1)

(viii) White phosphorus is generally kept in...... (10, Vol 1)

(ix) Solvay process is associated with the preparation of...... (11, Vol 2)

(x) Cations are......in size than the neutral atoms. (7, Vol 1)

2. (a) For three elements X, Y and Z, following data are given:

Element	Atomic mass number	Number of neutrons
X	35	18
Y	23	12
Z	24	12

Give the chemical formulae and nature of the compounds (electrovalent/covalent) formed between (i) X and X (ii) X and Y (iii) Z and X. (6, 7, Vol 1)

(b) A gas is allowed to expand at constant temperature from an initial volume of 300 ml to a final volume of 1 litre, where its pressure is 0.15 atmosphere. What was the original pressure? (4, Vol 1)

(c) A and B are two atoms in whose nuclei, the numbers of protons and neutrons are:

Atoms	Protons	Neutrons
A	6	6
B	6	7

Which element/elements do they represent and what is the relation between them? (5, Vol 1)

(d) Below are given some elements with their atomic radii.

Element	Cs	Li	K	Rb	Na
Atomic radii (Å)	2.25	1.34	1.96	2.11	1.54

Infer to which group of the periodic table they belong and how the atomic radius varies from top to bottom in a group in the periodic table. (7, Vol 1)

3. (a) With which element/compound the following are associated?

(i) Hall's process (11, Vol 2)

(ii) Nelson's cell (11, Vol 2)

(iii) Calamine (11, Vol 2)

(iv) Ostwald's process (10, Vol 1)

(b) When a solution of A is added to a solution of B, a white precipitate is obtained, which is completely dissolved in aqueous solution of C. When vapours of A and C are allowed to react, dense white fumes of compound D are produced. When compound D is heated with NaOH, vapours of C are again produced. Aqueous solution of C turns red litmus blue. Suggest the names of A, B, C and D. (13, Vol 2)

(c) How would you get a continuous stream of H_2S in the laboratory? Give the diagram and working principle of the apparatus used. (9, Vol 1)

4. (a) Explain any *two* of the following.

What happens when:

(i) H_2S is passed through an acidic solution containing Cu^{2+} and Zn^{2+} ions? (9, Vol 1)

(ii) solution of NH_3 is added to copper sulphate solution? (10, Vol 1)

(iii) Cl_2 is passed through KI solution which contains some starch? (8, Vol 1)

Or

Give reasons for any *two* of the following.

(i) SO_2 is not used for sterilizing drinking water. (9, *Vol 1*)

(ii) A solution of Na_2CO_3 absorbs more CO_2 than ordinary water. (11, *Vol 2*)

(iii) Blue colour of copper sulphate solution is destroyed when iron filings are added to it. (11, *Vol 2*)

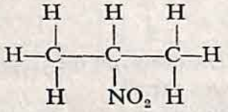
(b) When SO_2 gas is passed through saturated solution of H_2S, the following reaction occurs:

$$SO_2+2H_2S \rightarrow 2H_2O+3S\downarrow$$

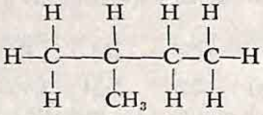
In the reaction which is a reducing and which is an oxidising agent? (14, *Vol 2*)

(c) Explain the chemistry involved in testing PO_4^{3-} ion. (10, *Vol 1*)

5. (a) Give the IUPAC nomenclature for the following compounds.

(i) 

$$\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{NO_2}{C}}-\overset{H}{\underset{H}{C}}-H}$$

(ii) 

$$\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{CH_3}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$$

(17, *Vol 2*)

Or

(b) Two separate solutions of A and B, contain 60 gm of each per litre. Molecular weight of A and B are 300 and 200 respectively. Calculate the ratio of the molarities of the two solutions. (13, *Vol 2*)

(c) Differentiate between any *two* of the following.

(i) Colloids and suspensions (13, *Vol 2*)

(ii) Molality and molarity (13, *Vol 2*)

(iii) Rapid combustion and spontaneous combustion (16, *Vol 2*)

1983

1. Give answers to each part in one or two words or a sentence.

(i) What is the pH of a 10^{-8}M hydrochloric acid solution? (17, *Vol 2*)

(ii) An element X is in the third group of the periodic table. What is the formula of its oxide? (7, *Vol 1*)

(iii) The atomic number of chlorine is 17. What is the number of electrons in Cl^-? (5, *Vol 1*)

(iv) What is the chemical formula for ferric carbonate? (3, *Vol 1*)

(v) What are zeolites? (12, *Vol 2*)

(vi) An element has 2 electrons in the M shell. What is the atomic number of the element? (5, *Vol 1*)

(vii) How many grams of sodium hydroxide should be dissolved in water to produce 500 ml of 0.1 M solution? (Na = 23, H = 1, O = 16). (13, *Vol 2*)

2. (i) Complete the following chemical equations.

(a) $CH_3COOH+C_2H_5OH \xrightarrow{\text{Conc. } H_2SO_4}$ (17, *Vol 2*)

(b) $P+HNO_3 \longrightarrow$ (10, *Vol 1*)

(c) $NaOH+Cl_2 \longrightarrow NaClO_3+$ (8, *Vol 1*)

(d) $Sb+Cl_2 \longrightarrow$ (8, *Vol 1*)

(ii) Given below are the melting points and the atomic radii of three elements X, Y and Z of the periodic table, each having *n* electrons in the outermost shell of their atoms.

Element	X	Y	Z
m.pts. (°C)	214	121	101
at. radii (Å)	1.20	1.31	1.36

Answer the following.

(a) Will the valencies of these elements be same or different?

(b) Which element will have the highest atomic number? (7, *Vol 1*)

(iii) Differentitate between a strong electrolyte and a weak electrolyte. (13, *Vol 2*)

3. (i) Fill in the blanks in the following sentences.

(a) HCl is...............molecule whereas H_2 is........... (polar/non-polar) (6, *Vol 1*)

(b) On going down a group in the periodic table, the metallic character of elements........... (7, *Vol 1*)

(c) The number of molecules in 2 g of neon (mol. wt. = 20) is........... (2, *Vol 1*)

(d) Isotopes have different mass numbers because their nuclei contain different number of........... (5, *Vol 1*)

(ii) 2 g of metallic sodium reacts with excess of water. What is the volume of hydrogen evolved at STP? (Na = 23, H = 1, O = 16). (3, *Vol 1*)

Or

Calculate the weight of oxygen required for burning completely 3.2 g of methane (C = 12, H = 1, O = 16) (3, *Vol 1*)

(iii) In the redox reaction:

$$A^{2+}+B \rightarrow B^{2+}+A,$$

name the oxidising agent. (14, *Vol 2*)

4. (i) Give the IUPAC names for the following compounds.

(a) HCOOH

(b) CH_3OH (17, *Vol 2*)

(ii) Name the metals which are extracted from the following ores.

(a) Bauxite

(b) Calamine (11, *Vol 2*)

(iii) Name the elements/compounds with which the following process are associated.

(a) Frasch process (9, *Vol 1*)

(b) Haber's process (10, *Vol 1*)

(iv) Decomposition of SO_3 is represented by the chemical equation:

$$2SO_3(g) \rightleftharpoons 2SO_2(g)+O_2(g)-Q\text{kJ}$$

Predict the influence of increase in (a) temperature and (b) pressure on this equilibrium. *(14, Vol 2)*

5. (i) Describe briefly one method for the preparation of carbon dioxide or sulphur dioxide in the laboratory. Draw a neat labelled diagram of the apparatus used. *(15, Vol 2; 9, Vol 1)*

(ii) Give chemical equations of reactions involved in any three of the following.

(a) Sulphur dioxide is passed through an acidified solution of potassium permanganate. *(9, Vol 1)*

(b) Chlorine is passed through potassium iodide solution. *(8, Vol 1)*

(c) A mixture of ammonium chloride and slaked lime is heated. *(10, Vol 1)*

(d) Burning magnesium wire is introduced in a jar containing nitrogen. *(10, Vol 1)*

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1979

1. (a) Rewrite the following information in the form of a balanced chemical equation.

Magnesium burns in carbon dioxide to form magnesium oxide and carbon. *(3, Vol 1)*

(b) An element has an atomic number 16. How many electrons will be present in K, L and M energy shells of its atom? What will its electrovalency be? *(5, Vol 1)*

Or: State one major difference between covalent and ionic bonds and give one example each of covalent and ionic compounds. *(6, Vol 1)*

(c) Rewrite any *two* of the following statements in a correct form after correction where necessary.

In a periodic table

(i) periods are the horizontal rows of elements.

(ii) groups have elements with consecutive atomic numbers.

(iii) elements in the same period have equal valency.

(iv) isotopes are the elements of the same group. *(7, Vol 1)*

(d) State any *two* of the following gas laws.

(i) Boyle's law

(ii) Avogadro's law

(iii) Graham's Law *(4, Vol 1)*

Or: Draw a graph to depict the following statement.

Volume of a gas is directly proportional to its temperature on the Kelvin scale and becomes zero when the temperature is zero. *(4, Vol 1)*

2. (a) State the reactions, if any, of the following metals with a solution of copper sulphate.

(i) Platinum (ii) Copper (iii) Iron (iv) Zinc

(b) Write the names of the elements known as halogens. Give one use for each of them. *(8, Vol 1)*

Or: Explain how a covalent compound like hydrogen chloride gives a solution in water which is acidic and electrically conducting.

(c) Give names of immediate neighbours of oxygen in the periodic table on its left, right and bottom side. What fraction of air by volume is oxygen? *(7, Vol 1)*

(d) State one reason for keeping nitrogen and phosphorus in the same group of the periodic table. Describe:

(i) action of phosphorus on a solution of caustic soda, and

(ii) action of ammonia on a solution of copper sulphate. *(10, Vol 1)*

3. (a) From amongst the following, choose the metals and the non-metals and state one of the properties on the basis of which you have made your choice.

(i) Graphite (ii) Sodium (iii) Red phosphorus (iv) Helium *(11, Vol 2)*

(b) (i) Describe a method for making permanent hard water soft. *(12, Vol 2)*

(ii) Give an example of a colloidal solution. *(13, Vol 2)*

(c) Give example of a reaction which stops before completion and reaches an equilibrium state. How can we shift this equilibrium in the direction of the forward reaction? *(14, Vol 2)*

4. (a) Give the names and structural formulae and one example of each of the following.

(i) Saturated hydrocarbons

(ii) Unsaturated hydrocarbons

(iii) Alkyl chlorides

(iv) Alcohols *(17, Vol 2)*

(b) State the characteristics of a good fuel and give two examples of gaseous fuels. *(16, Vol 2)*

Or: Describe one method of putting out a fire.

1980

1. (a) What is a proton? How does it differ from a neutron? *(5, Vol 1)*

(b) What is an electrovalent bond? What type of bond is present in $CaCl_2$ or Cl_2? (6, Vol I)

(c) Discuss the long form of periodic table. (7, Vol I)

Or: What are the advantages of periodic table?

(d) (i) What are valence electrons? (5, Vol I)

(ii) What are cathode rays and in what respect do they differ from positive rays? (5, Vol I)

Or: Describe the nuclear model of an atom. (5, Vol I)

2. (a) State Avogadro's law. What is its utility? (4, Vol I)

(b) (i) Why do the halogens not occur in free state in nature? (8, Vol I)

(ii) What is the difference between hydrogen chloride and hydrochloric acid? (8, Vol I)

(c) Sulphur dioxide exhibits both oxidising and reducing properties. Explain by giving one example for each. (9, Vol I)

(d) Using the equation $2KClO_3 \rightarrow 2KCl + 3O_2$ calculate the weight of potassium chlorate required to produce 8 g of oxygen (At. wt. of K = 39, Cl = 35.5, O = 16). (3, Vol I)

3. (a) What happens when (attempt any *two* giving equations):

(i) ammonium chloride is heated with slaked lime? (10, Vol I)

(ii) phosphorus is heated with caustic soda? (10, Vol I)

(iii) magnesium burns in carbon dioxide? (15, Vol 2)

(b) What is the difference between electrolytes and non-electrolytes? (13, Vol 2)

Or: How is hard water converted into soft water? (12, Vol 2)

(c) Discuss the place of phosphorus and nitrogen in the periodic table. (10, Vol I)

Or: Under what conditions do phosphorus and nitrogen react with hydrogen and oxygen? Give equations. (10, Vol I)

4. (a) What is the effect of concentration of reactants and temperature on the reaction rates? (14, Vol 2)

(b) What is graphite? Give its important properties and uses (2 each). (15, Vol 2)

(c) How is the gas used for domestic cooking obtained? Why is it called LPG? (16, Vol 2)

(d) Give one example each of saturated and unsaturated hydrocarbons. Give their structures. How would you differentiate between the two? (17, Vol 2)

1981

1. Give your answer to each part in one or two words or a sentence.

(i) What valency will be shown by an element having atomic number 15? (7, Vol I)

(ii) Name two salts which cause permanent hardness of water. (12, Vol 2)

(iii) Which allotropic form of sulphur is insoluble in carbon disulphide? (9, Vol I)

(iv) What is the name of the compound having the formula $Ca(H_2PO_4)_2$? (10, Vol I)

(v) Will the curve drawn between pressure and volume of a given sample of a gas, at a given temperature, be a straight line? (4, Vol I)

(vi) When two immiscible phases are dispersed to produce a colloidal solution, would you call such a solution homogeneous or heterogeneous? (13, Vol 2)

(vii) What are the constituents of producer gas? (16, Vol 2)

2. (i) Complete the following chemical equations.

(a) $CH_3COOH + PCl_5 \longrightarrow$ (17, Vol 2)

(b) $C_6H_6 + HNO_3 \xrightarrow[<60^\circ C]{H_2SO_4}$ (17, Vol 2)

(c) $P_4(\text{white}) + 3NaO + H_2O \xrightarrow{\text{Boil}}$ (10, Vol I)

(d) $BaCl_2 + K_2SO_4 \longrightarrow$ (10, Vol I)

(ii) Given below is a part of the periodic table:

Li	Be
Na	
K	
Rb	
Cs	
Fr	Ra

As we move vertically downward from Li to Fr,

(a) what happens to the size of the atom?

(b) what happens to their metallic character? (7, Vol I)

(iii) Explain why covalent compounds are generally low-melting.

3. (i) Fill in the blanks in the following sentences.

(a) Arrhenius proposed that most acids and salts break apart into......when dissolved in water. Evidence in support of this theory is that these solutions......an electric current. Substances whose aqueous solutions have this property are called......... *(13, Vol 2)*

(b) The amount of heat evolved when one mole of a substance is burnt completely in oxygen is called...... *(13, Vol 2)*

(c) Almost all the mass of an atom is concentrated in a small region of space called the...... *(5, Vol 1)*

(ii) A substance X was heated with slaked lime. A pungent smellings gas Y which gave thick white fumes with a rod dipped in concentrated hydrochloric acid, was liberated. Name the compounds X and Y and give equations for the reactions involved in the above statement. *(10, Vol 1)*

4. (i) Write IUPAC names of the compounds having the following formulae: (a) CH_3COCH_3 (b) C_2H_5CHO. *(17, Vol 2)*

(ii) Two chemical substances A and B when mixed at room temperature react very slowly. Suggest two different ways of increasing the rate of this reaction. *(14, Vol 2)*

Or: Quicklime is prepared by heating limestone in tall furnaces called lime kilns according to the following reaction:

$$CaCO_3 \rightleftharpoons CaO + CO_2\uparrow$$

During one of such operations, the top of the kiln remained blocked so that no carbon dioxide could escape from it. When the kiln was cooled and opened, it contained mostly limestone and very little of quicklime. How do you explain the formation of very little of quicklime? *(11, Vol 2)*

(iii) List the steps to be taken for obtaining a pure sample of copper from copper pyrites. *(11, Vol 2)*

5. (i) Describe briefly one method for the preparation of carbon dioxide or sulphur dioxide in the laboratory. Draw a neat diagram of the apparatus used. *(9, Vol 1; 15, Vol 2)*

(ii) Give chemical equations for the reactions involved in any *three* of the following cases.

(a) Chlorine is passed through a hot solution of sodium hydroxide. *(8, Vol 1)*

(b) Hydrogen sulphide is passed through an acidified solution of potassium permanganate. *(9, Vol 1)*

(c) Ammonia gas is passed through a solution of ferric chloride. *(10, Vol 1)*

(d) Action of conc. nitric acid on copper chips. *(10, Vol 1)*

1982

1. Give answers to each part in one or two words or a sentence.

(i) Name the process you would use to separate ammonium chloride from a mixture of sodium chloride and ammonium chloride. *(2, Vol 1)*

(ii) What is the number of water molecules contained in a drop of water weighing 0.06 g? *(3, Vol 1)*

(iii) What valency will be shown by an element having atomic number 17? *(5, Vol 1)*

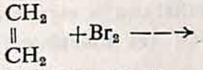
(iv) What is the chemical formula for zinc phosphate? *(3, Vol 1)*

(v) What is permutit? *(12, Vol 2)*

(vi) What is the maximum number of electrons the M shell of an atom can accomodate? *(5, Vol 1)*

2. (i) Complete the following chemical equations.

(a) $\underset{\text{(Conc.)}}{Zn+4HNO_3} \longrightarrow$ *(11, Vol 2)*

(b) 

$$\overset{CH_2}{\underset{CH_2}{\|}} + Br_2 \longrightarrow$$ *(17, Vol 2)*

(c) $\underset{\text{(Slaked lime)}}{Ca(OH)_2} + Cl_2(g) \longrightarrow$ *(8, Vol 2)*

(d) $2NH_3(g) + 3Cl_2(g) \longrightarrow$ *(10, Vol 1)*

(ii) Given below is a part of the periodic table.

Li	Be		B	C	N	O	F
Na	Mg		Al	Si	P	S	Cl

As we move horizontally from left to right:

(a) what happens to the metallic character of the elements? *(7, Vol 1)*

(b) what happens to the atomic size? *(7, Vol 1)*

Or: Rewrite the following statements after correction wherever necessary.

(a) The properties of the elements in a periodic table are a periodic function of their respective atomic weights. *(7, Vol 1)*

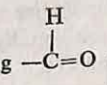
(b) The metallic character of elements in a period increases gradually on moving from left to right. *(7, Vol 1)*

(iii) The pH value of a solution of A is 2. What would you call A as: (a) non-electrolyte (b) weak electrolyte (c) strong electrolyte? *(13, Vol 2)*

3. (i) Fill in the blanks in the following sentences.

(a) Magnesium has two valence electrons in the...... shell. (At. no. of Mg = 12.) *(5, Vol 1)*

(b) Solvay process is used for the industrial preparation of....... *(11, Vol 2)*

(c) Organic compounds having 

$$-\overset{H}{\overset{|}{C}}=O$$ functional group are known as....... *(17, Vol 2)*

(d) In forming oxygen molecule......electrons are shared by the atoms of oxygen. *(9, Vol 1)*

(ii) Reaction between the reactants A and B proceed with the evolution of heat according to the following equilibrium:

$$\underset{\text{gas}}{A_2}+\underset{\text{gas}}{3B_2} \rightleftharpoons \underset{\text{gas}}{2AB_3}+\text{Heat}$$

Suggest two different ways of increasing the rate of formation of AB_3. (*14, Vol 2*)

Or: How many moles of hydrogen iodide would be obtained when 10 g of hydrogen combines completely with iodine? (at. wt. H = 1, I = 127) (*3, Vol 1*)

(iii) What would be the pH value of a 10^{-4}M HCl solution? (*13, Vol 2*)

4. (i) Write IUPAC names of the compounds having the following formulae: (a) CH_3COOH (b) HCHO. (*17, Vol 2*)

(ii) Name the metals that can be extracted from any *two* of the following ores: (a) Malachite (b) Bauxite (c) Haematite. (*11, Vol 2*)

(iii) How would you test the presence of an alcoholic group in an organic compound? (*17, Vol 2*)

(iv) 5.6 litres of a gas weigh 12 g at STP. What is the mass of 1 mole of the gas? (*3, Vol 1*)

5. (i) Describe briefly one method for the preparation of chlorine or hydrogen sulphide in the laboratory. Draw a neat labelled diagram of the apparatus used. (*8, 9, Vol 1*)

(ii) Give chemical equations for the reactions involved in any *three* of the following cases.

(a) Sulphur dioxide is passed through a saturated solution of hydrogen sulphide in water. (*9, Vol 1*)

(b) Chlorine gas is passed through a cold solution of sodium hydroxide. (*8, Vol 1*)

(c) Potassium chlorate is heated. (*9, Vol 1*)

(d) Copper turnings are heated with conc. sulphuric acid. (*11, Vol 2*)

1983

1. Complete the following statements.

(i) Presence of $MgCl_2$ causes......hardness in water. (*12, Vol 2*)

(ii) Element which reacts readily with cold water to give hydrogen is...... (*12, Vol 2*)

(iii) A colourless and odourless gas which turns lime water milky is...... (*15, Vol 2*)

(iv) Central part of the atom where neutrons and protons are held together is known as...... (*5, Vol 1*)

(v) In going across a period (right to left) in periodic table the atomic size of the atom...... (*7, Vol 1*)

(vi) A solution has pH = 4.0. The solution will turn......litmus to......litmus. (*13, Vol 2*)

(vii) The next higher homologue of ethyl alcohol is...... (*17, Vol 2*)

(viii) Chemical formula of washing soda is...... (*11, Vol 2*)

(ix) Physical state of iodine at room temperature is... (*8, Vol 1*)

(x) When NH_4Cl is heated with slaked lime, the gas given out is...... (*10, Vol 1*)

2. (a) A gas with a volume of one litre is cooled from 500°C to 0°C at constant pressure. What will be its volume now? (*4, Vol 1*)

(b) Classify the following into elements, compounds, and mixtures.

(i) Marble
(ii) Air
(iii) Gold
(iv) Brass (*2, Vol 1*)

Or

Write two chemical reactions of Cl_2 which show that Cl_2 acts as an oxidizing agent. (*14, Vol 2*)

(c) Below are given two chemical reactions. Which is *combination* reaction and which is *displacement* reaction?

(i) $2\ KBr\ (aq)+Cl_2\ (aq) \longrightarrow 2\ KCl\ (aq)+Br_2\ (aq)$

(ii) $Fe\ (s)+S\ (s) \longrightarrow FeS\ (s)$ (*14, Vol 2*)

3. (a) In the formation of a compound XY_2, atom X gives one electron to each Y atom. What is the nature of bonds in XY_2? Give two properties of XY_2. (*6, Vol 1*)

Or

Draw a neat labelled diagram of the apparatus used for the preparation of Cl_2 in the laboratory. Also write the chemical reaction. (*8, Vol 1*)

(b) An aqueous solution of compound A is allowed to react with chlorine water in presence of chloroform. A yellow brown layer is obtained in chloroform. Solution of A gives yellow precipitate of compound B with $AgNO_3$ solution. Compound B is partially soluble in aqueous ammonia solution. What are A and B? (*8, Vol 1*)

(c) Which cations are obtained, when the following salts are dissolved in water? Give their chemical formulae and charges.

(i) Ammonium chloride
(ii) Copper sulphate (*17, Vol 2*)

4. (a) What happens when (answer any *two*):

(i) aqueous ammonia solution is added to a solution which contains Fe^{3+}? (*10, Vol 1*)

(ii) concentrated H_2SO_4 is added down the sides of a test tube which contains a solution having $FeSO_4$ and KNO_3 salts? (*10, Vol 1*)

(iii) SO_2 gas is passed through a solution of H_2S? (*9, Vol 1*)

(b) Name the metals which can be extracted from the following ores.

(i) Calamine
(ii) Haematite (*11, Vol 2*)

(c) Explain the *counter current principle* used in the industrial preparation of bleaching powder. Draw the diagram. (*8, Vol 1*)

Or

What is nitrogen cycle in nature? (*10, Vol 1*)

5. (a) Give the chemical formula or symbol for the following.

(i) Slaked lime (*10, Vol 1*)

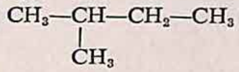
(ii) Diamond (*15, Vol 2*)

(b) How does CO react with the following? Give main products only.

(i) Cl_2 in sunlight

(ii) Heated Ni (50 to 80°C) (*15, Vol 2*)

(c) Give the IUPAC nomenclature for *one* of the following.

(i) 
$CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-CH_3$ (ii) HCOOH

(*17, Vol 2*)

Or

Give the Fehling's solution test for —CHO group. (*17, Vol 2*)

(d) Define calorific value of a fuel. Give two advantages of gaseous fuels. (*16, Vol 2*)

This is the second of the two volumes of *Revision in Chemistry* written primarily for students of classes 9 and 10 offering the Science Course A of the All India and the Delhi Board Secondary School Examinations.

The subject matter is presented in a question-answer format with the dual purpose of providing the subject matter to the students in a crisp form, and aiding them in preparing for the examinations.

Notable features of the book are the important definitions and laws given at the beginning of each chapter, and the physical and chemical properties of elements provided in tabular form. These will be useful to the students as ready reckoners.

Questions from the 1979-83 All India and Delhi Board Secondary School Examination papers, given at the end of the book, further enhance its usefulness.

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